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# THE PROBLEM OF GLARE IN HIGHWAY LIGHTING

By P. J. BOUMA.

**Summary.** After a short discussion of the concept of glare or dazzle and a survey of the various types of glare (direct, indirect, simultaneous and successive glare) as well as of the effects of glare (reduction in the visual faculties of the eye, fatigue, diversion of attention), the influence of glare on contrast sensitivity is analysed in some detail. An approximate formula given by Holladay is dealt with. Consideration is then given in turn to the effect of successive glare (after-effects), the feeling of discomfort and differences between observations by different observers (on the basis of investigations with 100 observers). A number of practical conclusions are then drawn.

One of the most important and at the same time one of the most difficult problems encountered in the study of highway lighting is that relating to glare or dazzle. The difficulties to be overcome are very varied in character. In the first place there appears to be no agreement as to what actually constitutes glare, whilst it is also difficult to determine what type of glare plays the principal part. No criterion for measuring the intensity of glare exists and there is perhaps no other branch of physiological optics, in which the personal equation enters more deeply than in this problem of glare or dazzle.

## What do we understand by glare ?

The various phenomena which are included under the generic term of "glare" may be classified under two heads:

1) The reduction in all visual functions of the eye which results when a portion of the retina is stimulated by a brightness which is far above the average brightness level at which normal vision and perception operate.
2) The feeling of discomfort (with the simultaneous diversion of attention and various fatigue effects) which an object of such exceptional brightness creates.

Frequently both phenomena occur simultaneously and in many cases it is thus essential to distinguish clearly between these two groups: The visual faculty of the eye can in fact already be appreciably reduced before the second group of phenomena exercise any influence.

A characteristic difference between these two groups is to be found in the fact that the ocular faculties of the human eye can be measured and expressed numerically in many different ways, whilst a similar evalution as regards discomfort phenomena is much more difficult and is often quite impossible.

That portion of the retina on which the dazzling light impinges, may be the same as that which we employ for visual perception. We then speak of direct glare. (This occurs, for instance, when we make an attempt to determine the form of a light source and also when we look directly at a light source and then try to distinguish an object with the same mean retinal area). A still more common case is when the exposed area of the retina does not coincide, with the area utilised for perception, (e.g. when our perception of objects on a highway is disturbed by insufficiently-screened stationary sources of glare or by the headlights of an approaching motor car). In this case we speak of indirect glare: the visual acuity of a portion of the retina is reduced because another part of the retina is over-stimulated [1]).

[1]) This diminution may be partly attributed also to the dispersion of the glare light in the various parts of the eye.

As is already apparent from the examples given above, the functioning of the eye can be affected during the presence of a dazzling source as well as subsequently after its removal from the field of vision. In the first case we have simultaneous glare and in the second successive glare ("after-effects"). In the investigation of the latter phenomenon the time is naturally an important factor.

**Criteria for Measuring Simultaneous Glare**

To investigate the dazzling effects of different sources of light under different conditions, we must evaluate the effect produced numerically. For this purpose a measurement is usually made of how far a specific property of the eye is adversely affected by the presence of a source of glare. Thus we can measure the reduction in contrast sensitivity, in visual acuity, and in the speed of perception, etc., for all of which the following general considerations apply:

1) The dazzling effect will be the greater, the higher the intensity of illumination $E$ which the source of glare produces at the eye.
2) The dazzling effect will be the greater, the smaller the angle of vision $\alpha$ between the object perceived and the glare source.
3) A given source of glare will have the greater effect, the lower the brightness values at which objects are to be perceived.
4) The differences between different types of light are very small.

Exhaustive measurements have been carried out regarding the effect of glare on contrast sensitivity; these measurements will now be discussed in some detail.

Contrast sensitivity in the absence of a source of glare is defined as:

$$K = \frac{H}{\Delta H}$$

where $\Delta H$ is the difference in brightness which can still be just distinguished against a background brightness of $H$ [2]). Glare causes a reduction in the contrast sensitivity by a fraction $P$ times its original value, thus:

$$K' = P\,K = H\colon \left(\frac{\Delta H}{P}\right).$$

In other words, in the presence of a source of glare the difference in brightness just perceptible to the eye is $\Delta H/P$.

[2]) See also Philips techn. Rev., **1**, 166, 1936 (fig. 4).

The diminution in contrast sensitivity due to glare can also be expressed as the so-called "equivalent veiling brightness" $H'$ instead of by the magnitude $P$. The equivalent veiling brightness is defined by Holladay as follows:

The difference in brightness still just perceptible would be similarly raised from $\Delta H$ to $\Delta H/P$ if in place of the source of glare an additional brightness $H'$ were introduced into the whole field of view. For $H'$ Holladay gave the following approximate formula:

$$H' = C\,\frac{E^n}{\alpha^m} \quad . \; . \; . \; . \; . \; . \quad (1)$$

where $H'$, $E$ and $\alpha$ represent the same as above and $C$, $n$ and $m$ are constants, which Holladay found had the following values: $C = 9.2$ (when $H'$ is expressed in candles per sq. m, $E$ in lux and $\alpha$ in degrees), $n = 1$ and $m = 2$.

Hence the veiling brightness is proportional to the amount of light emitted from the glare source and is inversely proportional to the square of the angle of vision between the object and the source of glare. We shall discuss the application of this formula for a specific case. We must take as a basis the relationship existing between the magnitudes $\Delta H$ and $H$ — in the absence of dazzling light sources — and which is shown in *fig. 1* for

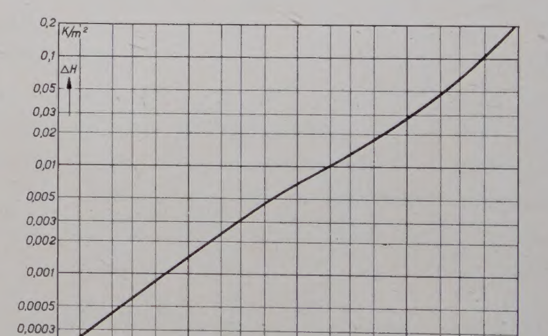


Fig. 1. Difference in brightness $\Delta H$ which is still just detectible, plotted as a function of the brightness $H$ of the background, both expressed in candles per sq.m. The figure is applicable for white light. The ratio of abscissal to ordinal values gives the contrast sentitivity.

white light. It is seen from this figure that, for instance, with a brightness $H = 0.3$ candle per sq. m, a brightness difference of 0.013 candle per sq.m is still just perceptible (contrast sensitivity $K = 23$). Now assume that a source of glare is introduced which has an intensity of 810 candles in the direction of vision and is 2 m to the side of the object to be perceived. The distance

between the eye and the source of glare is assumed to be 30 m, so that the intensity of illumination at the eye (due to the source of glare) is $E$ = 0.9 lux and $\alpha$ = 3.82° This case is described in the report of the Illumination Committee of the Royal Dutch Automobile Club and of the National Dutch Cycling Association (1925) as "just embarrassing glare". From (1) we get:

$$H' = 0.568 \text{ candles per sq. m}$$

Fig. 1 gives, for a brightness $H + H' = 0.868$ candles per sq.m, a value of $\Delta H$ of 0.03 candle per sq.m, so that the contrast sensitivity $K'$ is $0.3/0.03 = 10$ and has hence dropped to half.

It should be emphasised that Holladay's formula only gives the order of magnitude of the glare. Various investigators have found that it is subject to a number of deviations:

a) The value of $m$ varies from 1.5 (Stiles) to 4 (Rep. Roy. Dutch Auto. Club), whilst we have found that $m$ is closely dependent on the angle of view $\alpha$; for $\alpha$ between 2 and 15° an average value of $m = 2$ was found.

b) A source of glare situated above the object being viewed, has less effect than a glare source placed beside or below the object (Weigel, Bouma); this phenomenon is not taken into consideration in equation (1).

c) The values given by Holladay indicate that $n$ is also dependent on $\alpha$; as the angle of view increases $n$ diminishes; between 2.5 and 5° $n$ has a mean value of 90. We found a value of 0.89 for $n$ when $\alpha$ = 3.5°, so that the proportionality to $E$ is not strict.

d) In equation (1) the brightness $H_B$ of the glare source and the angle $\delta$ at which it is viewed are included only in the general term $E$ which is proportional to $H_B\delta^2$. The law which assumes that the effect of the glare source, with equivalent $E$, is independent of the particular values of $H_B$ and $\delta$ only holds good for sufficiently small sources of glare, i.e. where $\delta < \delta_0$. The limits for $\delta_0$ given by different investigators are: 3° (Bordoni), 1° (Stiles), 0.5° (Nat. Dutch Cycl. Assoc. A.N.W.B.). We have found that the law still gives satisfactory values at $\delta = 0.6°$

e) According to our measurements $H'$ was independent of $H$, as well as of $E$ and $\alpha$.

These deviations indicate, that the "equivalent brightness" cannot be regarded as a brightness value, which actually falls on the retina owing to light dispersion in the eye, but merely as a fictitious magnitude which facilitates the correlation of practical results. Measurements based on the reduction in visual acuity, speed of perception, etc., as a criterion lead to analogous results, but these cannot be so easily collated by introducing a veiling brightness.

The effect of the colour of the glare source is very slight in all cases. On comparing glowlamp and sodium light many investigators have, for instance, arrived at the same values apart from unavoidable experimental tolerances, whilst others have observed a slight advantage in favour of sodium light. In investigations carried out in these laboratories, in which 100 observers participated, a slight advantage in favour of sodium light was also found. The permissible intensity of the sodium glare source was on the average 1.086 times greater than that of a white glare source. The probable error in this value was 3%. In the case of 61% of the observers the sodium glare source gave a lesser reduction in $K$ than a white glare source of equivalent intensity, whilst 39% found the opposite.

**Successive Glare**

The following must be considered as criteria for the degree of successive glare:

a) The time during which an after-image of the glare source persists.

b) The time, following the removal of the glare source until the eye again adapts itself to its normal visual capacity.

Few comprehensive measurements have as yet been carried out on this aspect of the problem, although certain tentative conclusions may already be drawn from the measurements which have been made. Thus it has been found that in general the rays of shortest wave length (blue, violet) are the most trying in successive glare. In this respect, for instance, sodium light offers considerable advantages over glowlamp and mercury-vapour light. It was also observed that light sources with a high luminous intensity and of small dimensions produce more intense successive dazzle than light sources of the same degree of brightness but of greater surface area.

**Discomfort due to Glare**

The feeling of discomfort and disturbance, etc., caused by a source of glare is difficult to express numerically. Attempts have been made to adjust two sources of light to have the "same discomfort values" (Harrison), but without conspicuous success.

Measurements of fatigue based on the gradual reduction in the visual capacity of the eye in the presence of a source of glare persisting for a long time (e.g. a reduction in the speed of reading) have not led to any noteworthy results. Measurements carried out by Mouton indicate that in this particular case there is practically no difference between white glowlamp light and the light obtained when all wave lengths below 5000 Å (blue-green, blue, violet) are cut out ("Selectiva" light).

Since no reliable measurements have been made in this direction, an estimate of this factor must be based on general practical experience. The following conclusions appear to be justified:

1) Exactly as in the case of successive glare, a light source of high brightness and small dimensions here again produces more discomfort than an equally bright source of light with a larger surface of radiation.
2) In general the blue rays are mainly responsible for the discomfort produced. Hence yellow light (both monochromatic light given by the sodium lamp and "Selectiva" light) results in less discomfort than white light.

### The Personal Equation

In all the measurements described relating to glare, differences due to the personal equation of the observers are extremely marked. The extent of these differences will be shown by an outline of the results of measurements obtained in this laboratory with 100 collaborators.

For a given set of conditions (background brightness $H = 0.3$ candle per sq.m, illumination falling on the eye from the glare source $E = 2.1$ lux, angular distance between the object and the glare source 3.1 °) each observer had to determine the contrast sensitivity without the glare source, with a sodium glare source and with a white glare source, the latter of equivalent brightness. The average deviation of the result of an observer from the mean values was about 40 per cent; some deviations were as much as 300 per cent. In spite of this lack of agreement the following general conclusions could be drawn:

1) The 32 persons wearing spectacles exhibited a lower average contrast sensitivity than the other observers (1.2 times) even in the absence of a glare source. They also experienced greater discomfort from the glare source, so that their contrast sensitivity with this source was much lower (1.4 to 1.5 times) than that found by the other observers.
2) The ratio of the above factors $P$ for sodium and white light glare was on an average: $P_{Na} : P_{white} = 1.059$ (probable error approx. 0.022). The slight advantage in favour of sodium light is due mainly to the results obtained by the observers wearing spectacles (with an average of 1.128), whilst the observers wearing no spectacles found practically no difference (on an average 1.024).
3) The contrast sensitivity, both in the absence and presence of the dazzle source, was lower with older persons than with the younger observers. The reduction between 18 and 50 years of age was 1.48 without a glare source, 1.57 with a sodium source, and 1.69 with a white-light glare source. An example of this reduction with a sodium source of dazzle is shown in *fig. 2*. Each point represents the mean

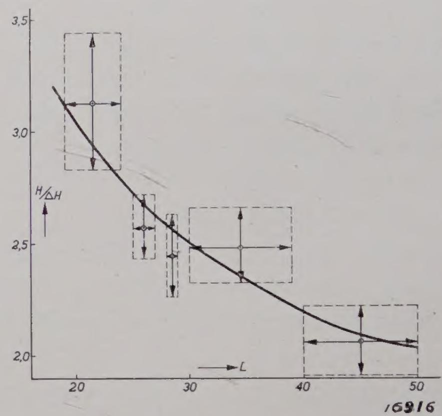


Fig. 2. The contrast sensitivity $H/\Delta H$ with glare due to sodium light as a function of the age of the observer (in years). The horizontal arrows represent the age group over which an average was taken, and the vertical arrows give the probable error. This curve was drawn on the basis of results obtained with 100 observers.

value of a definite group of observers. The horizontal arrows through these points indicate the particular age group, over which the mean value was obtained; the vertical arrows indicate the magnitude of the probable error.

4) The observers were also asked whether they found the sodium light or the white light more discomforting. 25 % expressed no opinion, whilst of the remainder 66 % suggested the sodium light was the more trying and 34 % the white light. The ratio $P_{Na} : P_{white}$ referred to above had a mean value of 1.092 for the first group, and a mean value of 0.947 for the second group. It was also found that there is some connection between the greater comfort afforded by one type of light on the one hand and better perception on the other hand, although it frequently happened that one light source gave

greater comfort whilst the other gave a greater ease of perception.

The experiments just described indicate, that measurements based on a small number of observers can only be employed with the greatest reserve for arriving at any conclusions.

**Practical Conclusions from the Above Considerations**

In every respect it is desirable for the eye to be exposed for as short a time as possible to a permanent source of glare which passes through its field of view. Precautions must therefore be taken that the light source does not radiate light over a small angle only (e.g. less than 15° against the horizon).

In view of successive glare and the discomfort produced it is desirable to give light sources low brightness values (i.e. large surfaces of radiation). In this respect an unscreened sodium light offers marked advantages over mercury light.

For the same two reasons it is advantageous to use light sources emitting few or no blue rays ("Selectiva" light for motor-car and cycle lamps, sodium light for stationary lamps).

By raising the brightness level of the highway surface, either by increasing the intensity of illumination or by improving the coefficient of reflection of the highway surface, the dazzle caused by various light sources can usually be reduced.

Glare due to other light sources on the highway is many times more powerful than that due to insufficiently screened stationary light sources, but the latter cause more discomfort than might appear on first consideration, mainly owing to their repetitive occurrence. The ideal solution is therefore to illuminate the highway principally by stationary light sources and to screen these sources in a proper way, so that they do not have a small angle of radiation against the horizon.

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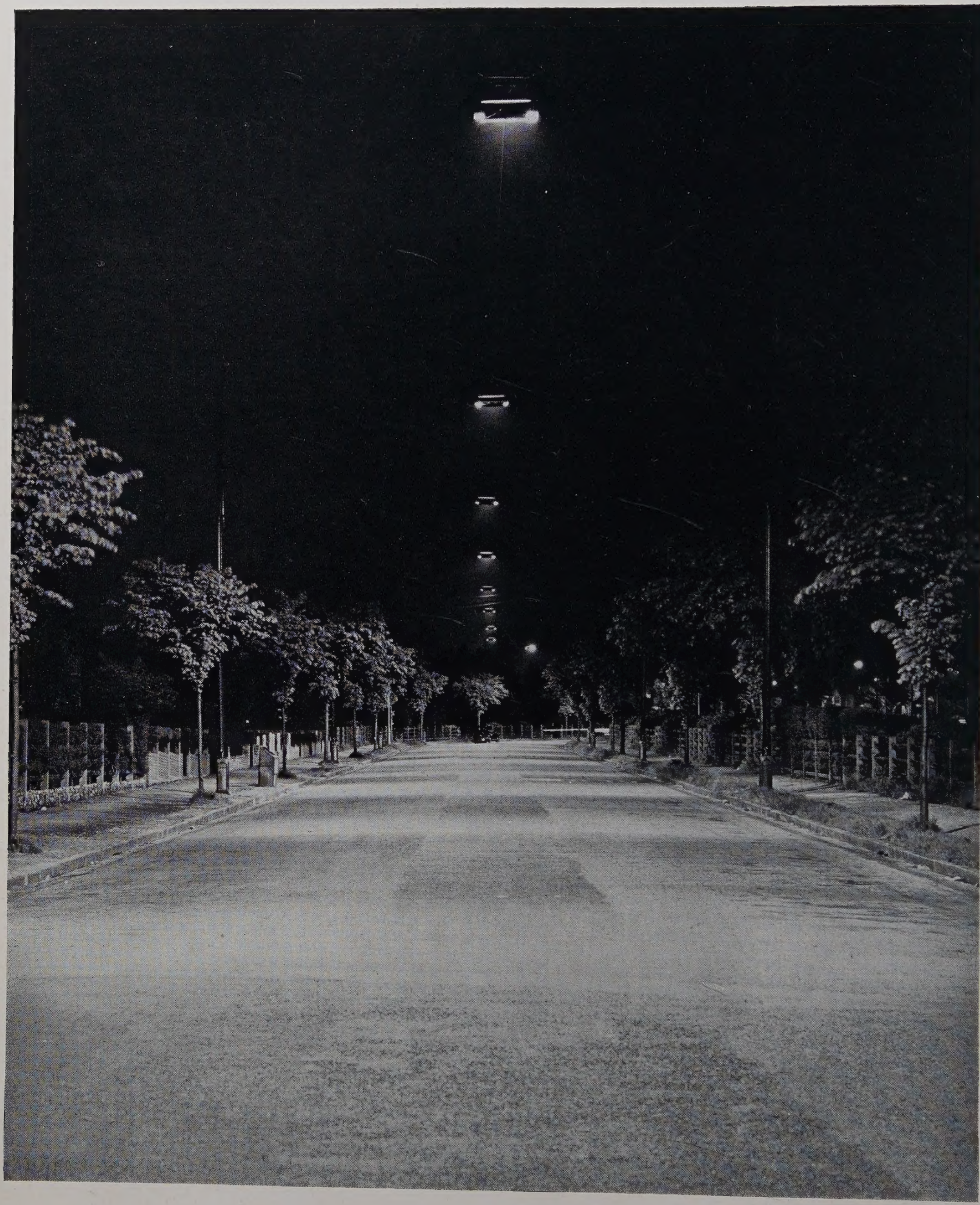
# THE NEW SODIUM LIGHTING SCHEME OF THE PURLEY WAY, CROYDON



Some time ago the extended sodium lighting scheme on Purley Way Croydon was put into operation. 235 "Philora"-SO-150 W.-lamps in Wardle Units provide an illumination of 1 footcandle under the lamps and 0.7 footcandles in the mid-span points on a stretch of road four miles long.

# THE RECORDING STRIP IN THE PHILIPS-MILLER SYSTEM

By C. J. DIPPEL.

**Summary.** A special registration strip has had to be evolved for the Philips-Miller system of sound recording, whose characteristics are discussed in the present article. The strip is composed of a gelatine layer at least 50 μ thick, the actual recording layer, which is deposited on a celluloid base. The recording layer carries a black covering layer of colloidal mercury sulphide, which is only 3 μ thick and entirely free from grain. By chemical treatment of the gelatin and the addition of special substances, it has been possible to obtain a transparent modulated sound track with sharp boundaries. Both coatings are made with a high degree of uniformity and within narrow thickness tolerances.

## Introduction

As already indicated in previous articles [1]), the "Philimil" strip, on which the sound track is traced by a mechanical sound recorder in the Philips-Miller system has to meet certain specific requirements.

A recording strip of this type consists of two coatings laid down on a celluloid base, viz, the recording layer, which must be at least 50 μ thick in view of the modulation width required and the form of cutter used, and the very thin covering layer. The latter must be completely or nearly opaque to those light rays for which the photo-electric cell has its maximum sensitivity. With the standard types of photo-electric cells this range of maximum sensitivity is situated in the infra-red of the spectrum. In addition the covering layer must absorb the light rays used for photographic printing of the inscribed positive, and also be as thin as possible.

The search for a suitable strip has thus a twofold purpose:

1) The production of a recording layer in which a sound track sharply defined at the edges can be cut without meeting an excessive resistance; and
2) The coating of this recording layer with a covering surface meeting the requirements set forth above.

## Requirements regarding Blackening and Transparency of a Transversal Sound Track

A number of requirements which the sound strip has to meet can be specified immediately.

It is naturally desired to obtain an adequate volume of sound from the sound track with a given amplification. The volume range is governed on the one hand by the ground noise, as the softest sounds must still be above the interference level, and on the other hand by the difference in transmission of light between the transparent and black portions of the sound track. For a given width of the stationary track this difference in fact determines the maximum variation in the fluctuations of light intensity falling on the photo-electric cell. If $T_H$ is the transmissibility for the bright portion of the strip and $T_Z$ that of the black portion [2]), then with a 100 % modulation the maximum amount of light falling on the photo-electric cell, and hence also the photo-electric current generated, is proporti-

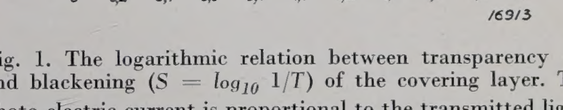



Fig. 1. The logarithmic relation between transparency ($T$) and blackening ($S = log_{10}\ 1/T$) of the covering layer. The photo-electric current is proportional to the transmitted light, whilst for a given substance the blackening is proportional to the thickness of the covering layer. It is seen from the diagram that above $S = 1.4$ the transparency (and hence the photo-electric current through the cell), diminishes only slightly, so that as regards maximum volume on reproduction, it is not necessary to make the covering layer thicker than is requisite for this intensity of blackening. With lesser blackening intensities the transparency diminishes much more rapidly. To bring the difference between the transparencies of the clear and black sound tracks ($T_H$—$T_Z$) as close as possible to the maximum value of unity it is therefore primarily necessary to make $T_H$ as great as possible.

1) See Philips techn. Rev. 1, 107, 135 and 211, 1936.

2) The transparency is $T = I_1/I_0$ where $I_0$ is the intensity of the incident light and $I_1$ the intensity of the transmitted light.

onal to $T_H$, and the smallest amount of incident light proportional to $T_Z$, so that the amplitude of luminous intensity is proportional to $(T_H - T_Z)$. The maximum value of $(T_H - T_Z)$ is unity, i.e. when the covering layer is completely opaque $(T_Z = 0)$ and the transparent layer has nil absorption $(T_H = 1)$.

How thick must the covering layer be so that $T_H - T_Z$ is sufficiently close to unity? In *fig. 1* the transparency is plotted logarithmically against the "blackening" $S$, the latter being defined in photography as $S = \log_{10} 1/T$ where $T$ is the transparency.

Hence at $T = 1$, $S = 0$
$T = 0$, $S = \infty$
$T = 0.1$, $S = 1$, and so on.

The blackening is proportional to the thickness of the black covering layer. If two layers with a blackening of $S = 1$ are laid one over the other, we get $S = 2$ (transparency $= 0.01$). Fig. 1 thus gives directly the required thickness of the covering layer. Little is to be gained by making the blackening of the covering layer greater than $S = 1.4$ $(T = 0.04)$ as measured with infra-red rays which are used for the reproduction, since above $S = 1.4$ the transparency is no longer much reduced, in other words by making the covering layer thicker the volume is not appreciably increased. For if a covering layer with $S = 4$ $(T = 0.0001)$ were used, which would no longer be transparent, the maximum volume would only be increased by 0.36 decibel, but to this end the covering layer should be three times thicker than with $S = 1.4$ [3]).

Summarising, we thus see that in order to reproduce a high volume sweep with a constant amplification it is essential for:

1) the blackening of the covering layer to be at least 1.4; a higher value offers little practical advantage.

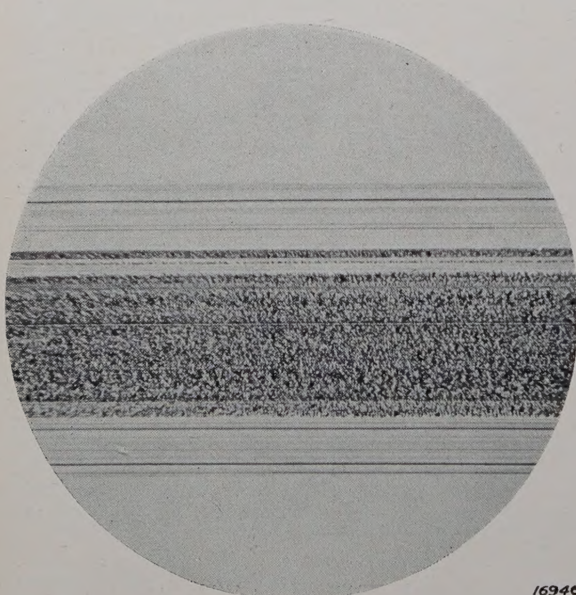
2) the transparency of the bright portion to be as great as possible; (a slight fog of say S = 0.06, would already reduce the light transmission from 1 to 0.87, i.e. by 13 per cent);

3) all causes liable to augment background noises to be avoided; the definition of the edges of the inscribed sound track must therefore be very sharp and the track itself must be as uniform as possible.

## The Recording Layer

A wide variety of materials may be used for making the recording layer. A choice was made of gelatin, since investigations had indicated that this material offered better prospects of successful

[3]) For if $T_H$ is put equal to unity the increase in the difference $T_H - T_Z$ is $1 : (1 - 0.04) = 1.042$, and the increase in volume is equal to the square of this value, viz, 1.086. The number of decibels is obtained by multiplying the common logarithm of this value (0.035) by 10. If the practical value of $T_H = 0.93$ is taken, we get 0.38 decibel.



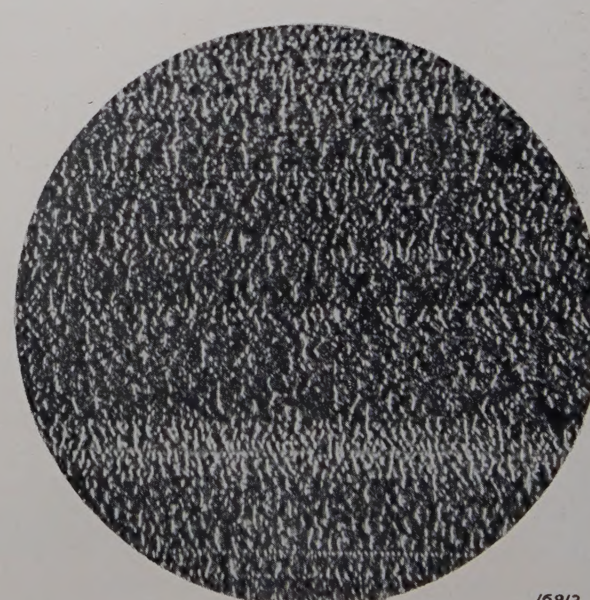




Fig. 2. The micro-photograph on the left (magnification × 60) shows a partially matt sound track in a clear gelatin layer. It is clearly seen how the matt portion strongly disperses the light and that the boundary between the matt and the bright areas is not sharp. The photograph on the right shows a matt sound track of 200 × magnification.

results than, for instance, nitro- and acetyl-cellulose coatings. In addition gelatin is comparatively cheap and the technology of producing multi-coated products has been thoroughly mastered in photographicfilm factories.

The sound track traced has to meet the following requirements:

1) The track traced must be well-defined and transparent.
2) The edges of the sound track must be smooth and straight.
3) The removed shaving must peel off easily; it must not adhere to the cutter and must not crumble.
4) The wear on the cutter must be reduced to a minimum.

Special attention has been given to the first requirement, viz., the transparency of the sound track. In many materials only a matt track can be inscribed, which has an appearance under the microscope as shown in *fig. 2*. The surface of this type of trace is wholly or partially rough, which naturally results in dispersion of the light rays and hence in reduced transmissibility, and if the matt effect extends to the edges this also leads to a want of definition at the track boundaries, which in turn is responsible for ground noise.

To ensure that the sound track is adequately transparent the gelatin must be subjected to specific chemical treatment, viz, partial decomposition.

Gelatin is a product of an albuminous nature and is made from animal albumens found in the connective tissues (muscles, tendons and corium) and in bones. The albumen occurs in these in the form of complex molecular chains with a more or less regular configuration in space. By treatment with bases the albuminous bodies are caused to swell, i.e. water is absorbed. If they are then heated (thermolysis) the weak bonds are broken and smaller molecular complexes of colloidal dimensions are produced. The resultant product is a colloidal gelatin solution made up principally of albumen molecules, except that the complex molecules have become so reduced in size that they form a colloidal solution in water. The configuration of the albumen chains is also much reduced as a result of this treatment.

The product so obtained, with which everyone is acquainted as household gelatin and as the principal constituent of glue, was found to be a suitable raw material for making the recording layer. The gelatin manufacturer, however, does not always supply a uniform product, since neither the final decomposition product he aims at producing, nor the raw material he uses, has to meet very specific requirements. This perhaps accounts for the fact, that one product exhibits better sound-registration characteristics than another. To obtain the desired characteristics and to ensure a supply of gelatin of uniform quality the decomposition process is continued a stage further under controlled conditions, during which the albumen molecules are themselves also attacked. The chains become shorter and the viscosity of the aqueous solutions drops considerably. If this process were continued indefinitely a molecular solution of amino acids (the well-known end products obtained on the total decomposition of albumens) would result, from which a coating could no longer be prepared. The process has therefore to be continued under well-defined conditions as regards hydrogen-ion concentration, temperature, density, etc., but only to a specific limit as measured by the viscosity.

What is achieved by this?

In the first place the differences between various gelatin deliveries are more or less eliminated and at the same time the resistance of the recording layer to the motion of the cutter is reduced. The most important point for the sound track traced in thus treated gelatin is to be perfectly transparent. Supplementary decomposition has, moreover, the great advantage that any foreign bodies present adhere less tenaciously to the recording layer and that filtration of the gelatin mass before coating is easier owing to the lower viscosity.

To prevent gelatin treated in this way from giving a brittle recording layer a water-soluble oil is added to the gelatin solution. The addition of this oil makes the dried recording layer very much more pliable and soft, so that the presence of the oil permits decomposition to be carried much further, than would otherwise be possible. On a correct choice of the hydrogen-ion concentration in the final coating product a little free oleic acid is retained in the dried recording layer and acts as a lubricant for the cutter, this being an advantage owing to the friction of the removed chip along the front of the cutter.

In this way decomposition and the addition of an oil furnish a recording strip giving a transparent sound track, a satisfactory continuous shaving and very good definition at the edges; moreover, any particles in the gelatin can be readily removed by filtering, and all impurities introduced later have a much less serious effect than with undecomposed gelatin.

### The Covering Layer

As is well known, [4]) a trace registered photographically is not sharply defined owing to the grain of the coating. In photographic films granulation has been a hitherto unavoidable consequence of the processing required to arrive at a high light sensitivity. As the "Philimil" strip does not need to be light-sensitive, the covering layer can be made entirely free from grain. Recent investigations have shown this to be desirable, since a granular edge on the sound track causes a by no means negligible increase in background noise.

It is obvious that the application of the covering layer must not in any way affect the characteristics of the recording layer. If, for instance, an exposed and grain-free silver-halide gelatin emulsion were deposited on the recording layer and subsequently developed as free from grain as possible, the finished product would have to be passed through developing and fixing baths which have a specific alkalinity and at the same time produce a more or less hardening effect. Even if developing, fixing and washing could be carried out under closely reproducible conditions, there is still the difficulty that the treatment required by the covering layer would adversely affect the cutting properties. It was therefore found necessary to apply the covering layer to the recording layer in such a way that no finishing operations were required; moreover, this also makes it technically easier to meet the very severe requirements as regards freedom from impurities and foreign substances.

As a rule the material for the black, covering layer is prepared separately and spread on the recording surface in the form of a black solution mixed with gelatin. It is obvious from the above considerations that the covering power of the black substance must be very high, in other words the requisite blackening of at least 1.4 must be attainable with very thin layers. Many dyes which, when mixed with gelatin or adsorbed in it, give a satisfactory blackening in thick layers, cannot be used owing to their lack of covering power. It must be remembered in this connection that at the edges of the sound track the thickness of the covering layer decreases to zero owing to the wedge-shaped form of the cutter. The greater the covering power, the smaller will be the area at the wedge having a blackening of less than 1.4.

The covering layer of the "Philimil" strip consists of a black mercury sulphide sol which is easily prepared by chemical means and which, similar to other metallic sulphide sols and metal sols, possesses a high covering power. (A sol is defined as a colloidal solution containing no grains visible under the microscope).

With a colloidal mercury-sulphide solution 1 mg per sq. cm already gives a blackening in the infrared of 2.5 to 5, according to the method of preparation. It is seen from *fig. 3* that the blackening

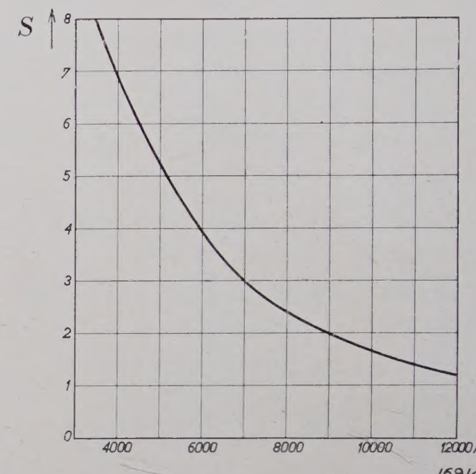



Fig. 3. Light absorption by the covering layer of a "Philimil" strip. The covering layer of this strip was 2.4 μ thick. It is seen, that the blackening with the light used for printing (approx. 4000 Å) is three to four times greater than with the light used for reproduction (approx. 8000 Å), in other words the "covering power" of this coating is three to four times greater with the printing light.

in the visible part of the spectrum and particularly in the ultra-violet is much greater still. This feature is of great advantage in the photographic printing of the "Philimil" positive.

The thickness of the covering layer is 3 μ, although it is technically possible to obtain the requisite blackening with much thinner layers. To guard against mechanical damage a lesser thickness is, however not used.

No granulation can be observed even under the microscope in the mercury-sulphide covering layer, if it is carefully prepared. On comparing under the microscope a high frequency registered by the Philips-Miller process with the same frequency registered photographically, the greater definition of the former will be apparent at once (see *fig. 4*). This is due to the fact that the absence of grain in the "Philimil" strip firstly ensures high definition at the edges of the track and secondly makes it impossible for the apices to be masked by light dispersion at the grains. The latter point constitutes a reduction in amplitude and, in photographic registration, always results in losses in the high-frequency range. Fortunately, in the Philips-Miller

[4]) See Philips techn. Rev. 1, 107, 1936.

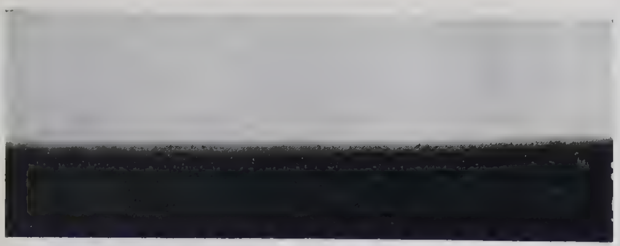


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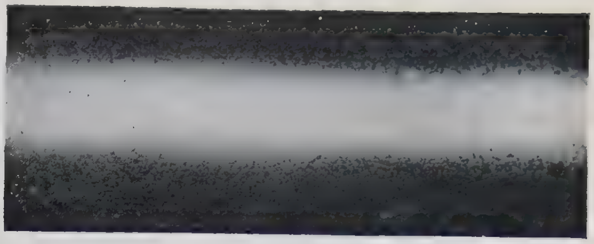
Fig. 4. a) Edge of an unmodulated Philips-Miller sound track. magnification × 100. The absence of granulation is clearly visible also in the transparent part removed by the cutter wedge.



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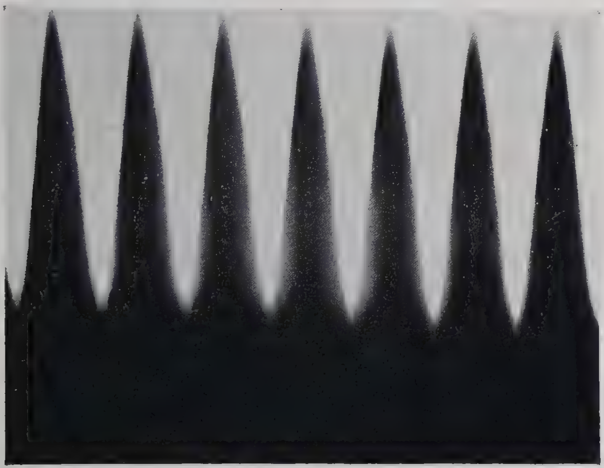
b) For comparison with fig. 4a: a micro-record of a stationary track on an experimental film of good quality (photographic process).



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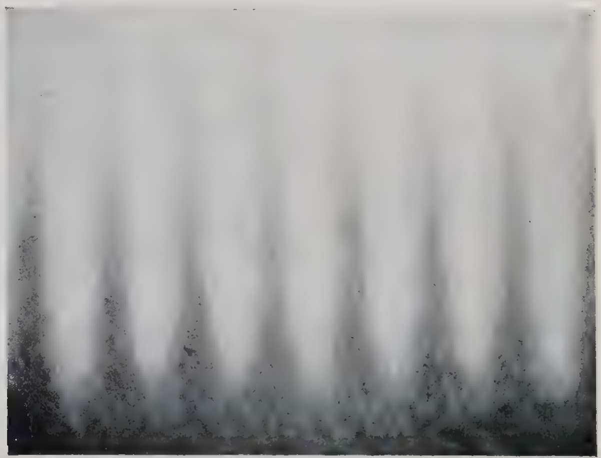
c) Micro-photograph with same magnification (× 100) of a sound track obtained by the Philips-Miller process (positive) for a frequency of 5000 cycles.



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d) The same as obtained on the experimental film (photographic positive).

mechanical-registration system there is no limitation in this direction.

**Finishing**

The manufacture of the "Philimil" strip on the basis of the experimental results indicated above was, however, at the outset still fraught with various difficulties, which have in the meantime been overcome.

Attention must first be called to the very important requirement that the finished product must cause the minimum amount of wear of the cutter. Wear of the cutter is principally due to the impact of the instrument during registration against inhomogeneities in the gelatin layer. By the special method of pre-treatment of the recording layer cutter wear has been reduced as far as possible; nevertheless any impurities or foreign bodies present may still cause damage to the cutter edge. Every care must therefore be taken to avoid all impurities and to keep the materials as clean and free from dust as is practicable in each finishing stage.

Foreign bodies must naturally be avoided both during the preparation of the coating material and during the coating process itself. Thorough straining through various filter units is repeated many times, after which the now thoroughly clean material has to be spread on a large surface of celluloid. This is done by passing the celluloid base over a roller to bring it in contact with the solutions, a certain portion being taken up by the strip. A greater or smaller part of the gelatin layer or of the covering layer sol adheres to the base and is caused to flow over it, the amount depending on the temperature and rate of travel of the base and the viscosity of the solution. After drying, the celluloid is coated with a black layer 50 μ thick. It is evident that both the coating and the drying processes must take place in a perfectly dust-free atmosphere. Also in all subsequent operations, such as cutting to the requisite width of say 7 or 17.5 mm, and perforation, no precaution must be omitted to prevent dust from being deposited on the film. After manufacture the product is scrupulously tested for potential cutter wear.

### Uniformity in Thickness

A further source of error in sound registration and reproduction is introduced by variations in thickness of the "Philimil" strip, for the sound recording system with cutter are stationary and the registration strip is stretched taut on a recording drum. A gradual reduction in thickness of say a total of 25 μ would reduce the width of a stationary track from 1 mm down to zero. Variations in thickness over the whole length of a strip, 300 m long, must therefore be kept within narrow limits of a few μ. The finishing processes are so devised, that the total variation in thickness cannot exceed about 6 μ and over short lengths not more than 4.5 μ, whilst the thickness of the recording layer is not below a certain minimum.

Uniformity in the thickness of the covering layer, i.e. in the blackening, is largely dependent on the case with which the covering layer sol can be spread on the recording layer. By adding various substances, which, *inter alia*, reduce the surface tension of the sol, the spreading power can be favourably influenced. The covering layer is made extremely uniform by suitable adaptation of the two layers to one another.

The above considerations indicate that the product in question here is one which has to meet very severe requirements. By systematic research it has been found possible to satisfy these desiderata in every respect.

# AN IMPULSE-VOLTAGE GENERATOR FOR TWO MILLION VOLTS

By A. KUNTKE.

**Summary.** The method of operation and the construction of an impulse voltage generator rated for 2 000 000 volts with symmetrical voltage distribution against earth is described. By suitable construction the dimensions of the equipment have been made extremely small.

A few months ago an impulse-voltage generator with an output of 2 × 1000 kilovolts against earth and 2000 kilovolts across the poles was constructed at the Philips X-Ray Laboratory. The method of operation and construction of this generator are described in the present article.

As is well known, impulse-voltage generators are in common use in electrical engineering, e.g. for testing insulators and leading-through units, since impulse voltages afford a ready means of simulating artificially the effects of over-voltages created in high-tension networks as a result of atmospheric disturbances and switching operations.

Short-period voltage impulses are usually produced by imparting a heavy charge to a condenser and then passing the charge to a resistance through a suitable switch — a flash-over spark gap being used in practice for this purpose. The voltage applied to the resistance thus abruptly increases from zero to the potential of the condenser at the instant the flash-over occurs; it then falls again as the condenser discharges through the resistance.

This simple case is illustrated in *fig. 1.* If the

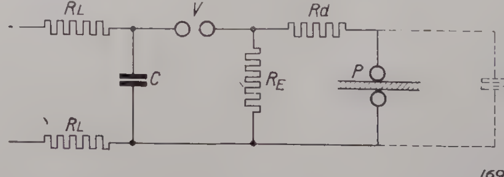


Fig. 1. Diagrammatic sketch of an impulse voltage circuit. The object $P$ under test (with capacity $C_p$) is connected to the condenser $C$ through a series resistance $R_d$ and the spark gap V. The condenser is charged through $R_L$ and at the flash-over at V is discharged through $R_E$. A voltage impulse is thus applied to the object $P$ under test.

condenser $C$ is slowly charged from an undefined D.C. source through the resistance $R_L$ a spark-over will occur at the sphere gap $V$ when the breakdown voltage is reached.

Thus, by choosing a suitable rating for the resistance

$R_E$ the rate of voltage-drop at the resistance can be varied for a specific size of condenser.

If only the discharge resistance $R_E$ is present in the circuit, its voltage will increase in an infinitely short period of time to the voltage $U_c$ applied to the condenser at the instant the flash-over occurs, and then decreases again according to the equation:

$$U_R = U_C \cdot e^{-t/C\,R_E}$$

The object $P$ to be submitted to the impulse voltage is connected in parallel to the discharge resistance $R_E$; in general $P$ has a capacity $C_p$. To avoid an oscillation being superimposed on the impulse, such as might be produced by the series capacity of $C$ and $C_p$ and the self-induction of the circuit, a damping resistance $R_d$ is provided which suppresses these oscillations.

The damping resistance $R_d$ in its turn affects the character of the voltage impulse applied to the test object $P$, since its self-capacity $C_p$ must be charged through the resistance $R_d$ at the beginning of the voltage impulse.

The voltage impulse applied to the test object $P$ is thus made up of two components:

1) The voltage increase (the wave "front") which is determined principally by the damping resistance $R_d$ and the capacity $C_p$ of the test object, and
2) the voltage drop (the wave "tail") which is governed mainly by the capacity $C$ and the discharge resistance $R_E$. It is assumed here that $C_p$ is small compared to $C$.

The variation of a voltage impulse with time is shown graphically in *fig. 2*.

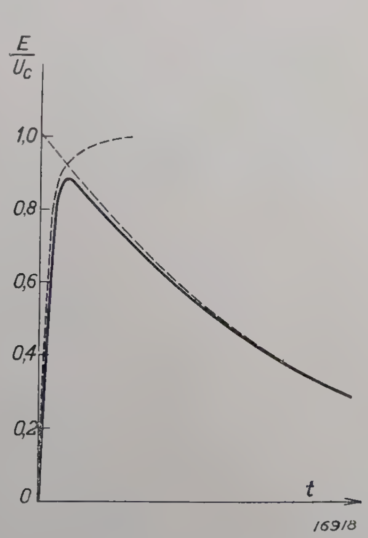


Fig. 2. Time function of a voltage impulse. The front is determined by the charging of the self-capacity $C_p$ through resistance $R_d$, whilst the descending portion of the curve is determined by the discharge of the capacity $C$ through the resistance $R \cdot U_c$ is the charging potential of the condenser $C$; the voltage applied to the test object is smaller than $U$

For testing insulators the time gradients of the front and of the tail have been standardised in a number of countries in order to furnish comparable results of tests. The gradient of the front is defined by the time taken for the voltage applied to the test object to rise from zero to half the maximum potential, whilst the gradient of the tail is expressed by the time taken for the voltage to drop from its peak value to half that value. An impulse wave of 0.5/50, i.e. in which the half-value time of the front is $0.5 \cdot 10^{-6}$ sec and the half-value time of the tail is $50 \cdot 10^{-6}$ sec, is in common use.

To generate very high impulse voltages (over approx. 200 kilovolts) the method of voltage multiplication described by Marx is universally adopted. The impulse generator built by Philips is also constructed on this principle, whose method of application may be suitably described with reference to the circuit diagram of Philips impulse generator given in *fig. 3*. In Marx's multiplication circuit a group of condensers are charged in parallel and then connected in series by the flashover at the spark gap. In fig. 3, $C$ are the condensers which are shunted by the resistances $r$ and charged through the charging resistance $R$ from a 180-kilovolt D.C. generator. To ensure that all condensers have the same charging characteristic and are all raised to the same potential after a specific charging period, the resistances $r$ have been made small as compared with the common charging resistances $R_L$. Spark gap $V$ — the ignition spark gap — of the group of spark gaps shown in the figure is somewhat smaller than the other gaps, and thus gives the first flash-over. The potential at the succeeding spark gap is in consequence increased and thus also gives a flash-over, in this way initiating in succession the flash-overs of the succeeding spark gaps. This sequence of spark-overs takes place in an extremely short interval of time so that all condensers $C$ are connected in series through the spark gaps and are discharged through the two discharge resistances $R_E$. The discharge circuit is indicated in fig. 3 by the heavy lines.

As indicated in the diagram, the impulse generator is built in two halves, each made up of 7 condensers together with the associated resistances and spark gaps; each condenser is charged to 150 kilovolts, thus giving a total potential of 2000 kilovolts in series. The maximum voltage against earth occurring at each discharge resistance and in each half of the generator is 1000 kilovolts.

The two halves of the impulse generator are shown in *fig. 4*; in the background is the 180-kilovolt D.C. source enclosed in a suitable housing, the direct

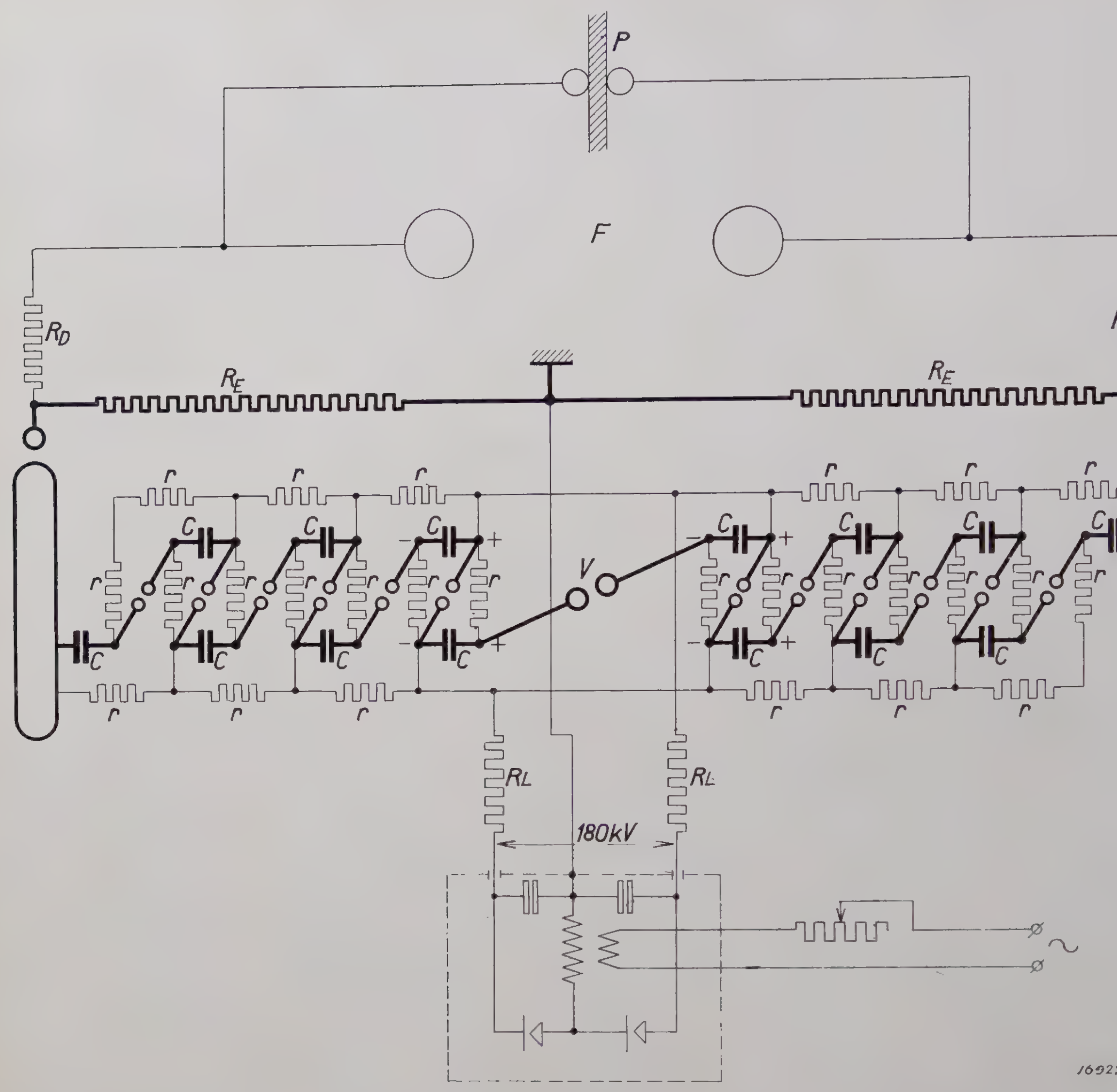


Fig. 3. Circuit diagram of the 2000 kilovolt impulse-voltage generator. All condensers $C$ are charged from the 180-kilovolt D.C. source through the resistances $R_L$ and $r$. At the instant of flash-over at the spark gap $V$ the potential at the other spark gaps is raised, so that a flash-over is obtained at these also. The circuit, then set up, is shown by the heavy line in the diagram; it is seen that all condensers $C$ are discharged in series through the two discharge resistances $R_E$. By adopting a construction in two halves and earthing the centre of the resistances $R_E$, the potential is symmetrical with respect to earth. The voltage applied to the test object $P$ is measured by means of the spark gap $F$.

voltage being furnished by high-tension rectifying valves. At floor level between the two pillars are the spark gaps and on the front of each pillar is the discharge resistance in the form of a wire resistance oil-immersed in a glass tube. The spark gaps with 10 cm spheres and the liquid resistances acting as charging resistances are also shown.

The small overall height of the equipment is due to the compact design of the condensers. By making the outer walls of exceptionally strong insulating material it has been possible to employ the condensers as supporting members for the rest of the equipment. The constructional details are the same as adopted in certain of our X-ray apparatus [1]). A new feature as regards impulse voltage generators is the large metal electrode at the top, which has been found to serve a useful purpose in preventing flash-overs between the top constructional members at the instant the voltage impulse is applied. If this electrode is absent, premature discharges to earth occur at the high-tension metal units during the application of the voltage impulse, which in certain circumstances may induce the flash-over at a partial potential level, e.g. at the top condenser. The

[1]) See Philips techn. Rev., 1, 6 and 178, 1936.

field intensities are reduced by the screen electrode to such an extent that these flash-overs are avoided.

The technical data of the equipment are given below:

The 2 × 7 condensers are rated for 0.01 μF per unit. At 150 kilovolts per condenser an impulse voltage of 2000 kilovolts is obtained. The impulse energy is then approx. 1.5 kilowatts per sec. The discharge resistance (oil-immersed metal resistance) is rated for 2 × 70 000 ohms, this giving a half-period value of the wave tail of $70 \cdot 10^{-6}$ sec.

To retain the general simplicity in design of the equipment, means for the common regulation of the intermediate spark gaps have been dispensed with; the spark gaps must be adjusted individually, although if required a common control for the gaps can be provided without appreciable modification in design.

The overall height of the pillars is 3 m, each pillar having a base area of 0.8 · 1.3 m. Compared with the performance of the equipment these dimensions are extremely small.

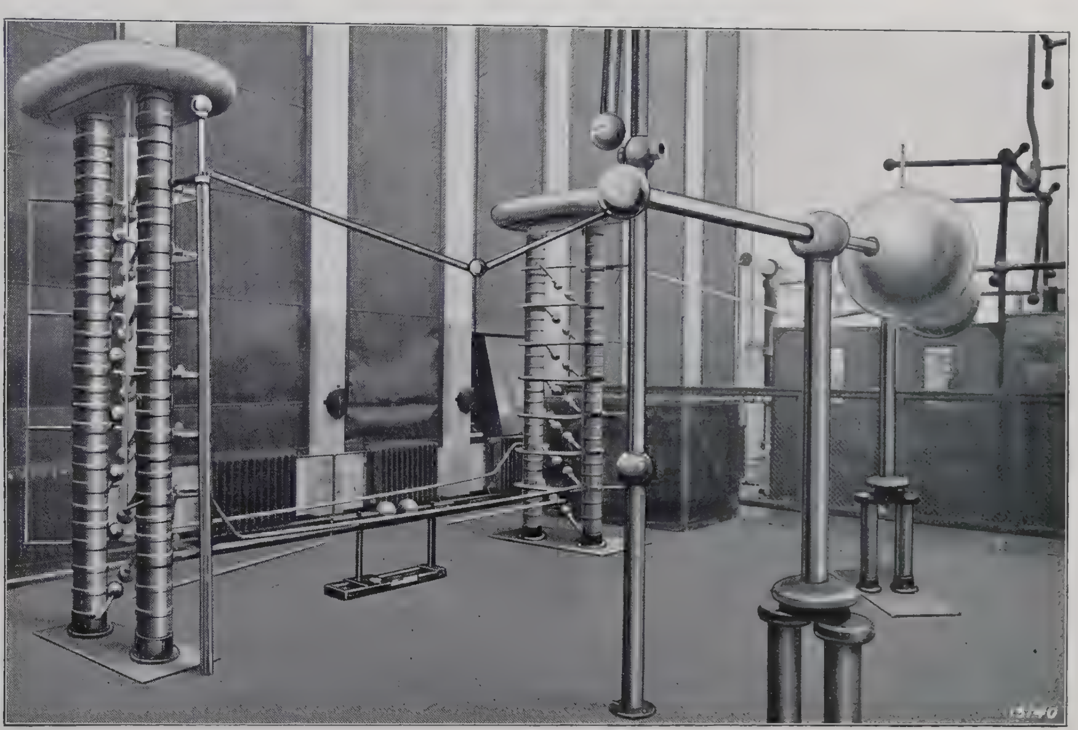

Fig. 4. Construction of the 2000-kilovolt impulse-voltage generator. At the rear is the enclosed 180-kilovolt D.C. source; between the two pillars is the ignition spark gap V. The discharge resistances $R_E$ are located on the fronts of the pillars, the condensers being constructional members of the two pillars. The upper screen electrodes, which prevent partial flash-overs, are also shown. The sphere gap for measuring the total voltage and the connected test object are not shown in the picture.

# ELECTRICAL FILTERS I

Vacation Course, held at Delft, April 1936.

By BALTH. VAN DER POL and TH. J. WEIJERS.

**Summary.** In this series of articles (originally forming a vacation course) the theoretical and practical constructional principles relating to electrical filters are discussed. The general characteristics of networks compounded of an arbitrary choice of impedances provide a starting point; various equivalent networks for any arbitrary filter are also dealt with. The properties of the simplest types of filter units in common use are deduced and then applied to high-pass, low-pass and band-pass filters. It is shown how, from these filter units, a compound filter can be built up to meet specific requirements. Finally, circuit-closing phenomena with low-pass and high-pass filters are discussed. In this first article an introduction is given to the general characteristics of linear networks and filters.

## Introduction

Electrical filters are networks with a number of external terminals whose branches are composed of impedances of which all or some are dependent on the frequency. The most common form of filter has two primary and two secondary terminals. A network with four external terminals is called a four-pole or quadripole; if there are two primary and two secondary terminals the network is termed a di-dipole. As the impedances are dependent on the frequency, the ratio of the secondary current to the primary current is also dependent on the frequency. The general purpose of filters is to permit, the free passage with minimum attenuation of frequencies within one or more specific frequency ranges, the frequencies in all other ranges being attenuated. The transmitted frequency range is termed the transmission band and the latter the attenuation band.

The filters in most common use are the following:

a) Low-pass filters, which permit those frequencies to pass with minimum attenuation which are below a specific limiting value and attenuate all frequencies above this limit.

b) High-pass filters, which permit frequencies to pass with minimum attenuation which are above a specific limiting frequency and attenuate all frequencies below this limit.

c) Band-pass filters, which permit only frequencies to pass with minimum attenuation which are situated within specific frequency limits and suppress all frequencies beyond these limits.

Between the transmission and attenuation bands there is always a transition range; in fact it is fundamentally impossible to obtain a discontinuous (sharply-defined) limit between these two bands if all frequencies pass through the filter with the same velocity, such that the phase lag is proportional to the frequency. For it can be shown mathematically that such a filter would cause a signal to arrive before it has been transmitted, which is naturally impossible.

Electrical filters find their principal use in telegraphy and telephony as well as in cable and wireless circuits and in television.

The fundamental principles on which the theory and construction of filters are based, were developed by Lagrange (1736—1813), Heaviside (1893), Campbell and K. W. Wagner (both in 1915) and in subsequent years by Zobel, Carson, Le Corbeiller, Brillouin, David, Cauer, Bode, Küpfmüller and others.

The theory of filters may be divided into two sections:

Filters with a sinusoidal e.m.f.; and

Filters operating under the action of an impulse or an abruptly-applied and subsequently-constant voltage (transient phenomena).

### 1) Filters with sinusoidal e.m.f.

The theory of these filters can be developed in a variety of ways. In their most recent analysis the theory of matrices and groups, as well as complex functions, occupies a prominent position. If consideration is restricted to the practical design of filters, the application of elementary mathematical analysis already permits substantial progress to be made. The hyperbolic sine and hyperbolic cosine functions are extensively employed, being defined as follows:

$$\sinh T = \frac{1}{j} \sin jT = {}^1/_2\,(e^T - e^{-T});$$

$$\cosh T = \cos jT = {}^1/_2\,(e^T + e^{-T}).$$

and analogous to: $\cos^2 T + \sin^2 T = 1$ we also have:

$$\cosh^2 T - \sinh^2 T = 1.$$

2) Behaviour of filters under impulses (transient phenomena).

The study of this subject requires the application of the higher branches of mathematics, although with the aid of the operational calculus of Heaviside we can in many cases reduce the requisite calculations to an elementary form.

**Division of Lectures**

The subjects to be dealt with have been spread over four lectures as follows:

Lecture I (van der Pol): Introduction into the general characteristics of linear networks and filters;

Lectures II & III (Weijers): Application of fundamental principles to the practical treatment of special filters with sinusoidal e.m.f.;

Lecture IV (van der Pol): Switching operations with low-pass and high-pass filters.

## INTRODUCTION INTO THE GENERAL CHARACTERISTICS OF LINEAR NETWORKS AND FILTERS.

Consideration will be restricted to networks which are:

1) Linear, i.e. the components (resistances, self-inductances, capacitances and mutual inductances) are independent of the current or voltage;
2) Passive, i.e. having no internal source of energy;
3) Containing only positive components, except mutual inductances, which can also be negative;
4) Invariable, i.e. the characteristics of the components do not vary with time;
5) Free from gyroscopic terms, thus conforming to the reciprocal theorem described below. This condition is always fulfilled under the conditions 1—4, if the elements of the filtor are not coupled with a mechanical system or if this coupling is purely electrically.

These networks conform to three fundamental principles:

1) Principle of Superposition

If in a circuit an e.m.f. $E_1(t)$ applied to the branch $A$ produces a current $I_1(t)$ in another branch $B$, and a subsequent e.m.f. $E_2(t)$ in $A$ produces a current $I_2(t)$ in $B$, then according to the principle of superposition, if the sum of the electromotive forces $E_1(t) + E_2(t)$ is applied in $A$, the current obtained in $B$ will be the sum of the current $I_1(t) + I_2(t)$, or in other words; if two forces act at the same time, the result is the sum of the results obtained if either of the two forces act alone.

2) Reciprocity Theorem

The reciprocity theorem states that if an e.m.f. $E_k(t)$ applied to the $k$-th branch produces a current of $I_{kl}(t)$ in the $l$-th branch, then if subsequently the same e.m.f. $E_k(t)$ is applied to the $l$-th branch, the same current $I_{kl}(t)$ as previously obtained in the $l$-th branch will be obtained in the $k$-th branch.

3) Conservation of Frequency

The principle of the conservation of frequency states that if a sinusoidal e.m.f. with a frequency $\nu_o$ is applied to any branch circuit of the system, then all other voltages and currents in the system will have the same frequency $\nu_o$.

**Simplification of Networks**

In networks with the above characteristics a node with $n$ converging branches can always be converted into a complete $n$-sided polygon for a specific frequency, without the voltages and currents in any of the other branches being altered. By a "complete" $n$-gon is implied that in addition to the $n$ sides all diagonals are also present. A complete $n$-gon thus has a total of $^1/_2\, n\, (n-1)$ branches.

By a single application of this transformation the number of nodes in the network is reduced by one; so that by repeated transformation it is possible to eliminate all the nodes from a network with the exception of the external terminals. We shall discuss here only networks with four external terminals, so that the network can be reduced to a complete quadrilateral (see *fig. 1*) made up of $^1/_2 \cdot 4 \cdot (4-1) = 6$ elements. The most

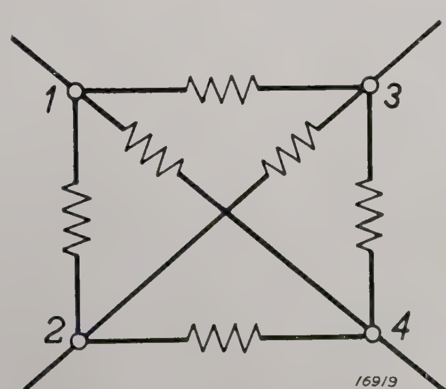


Fig. 1. Six impedances forming a complete quadrilateral and to which any arbitrary quadripole can be reduced.

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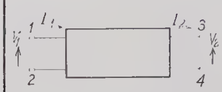
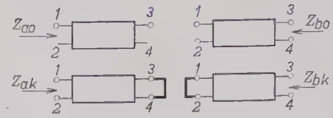
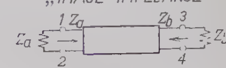
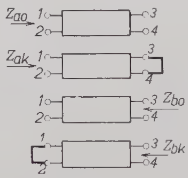
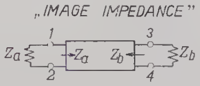
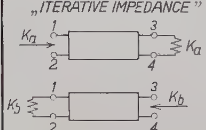
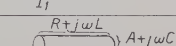
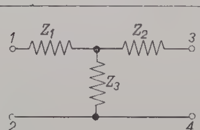
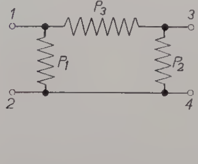
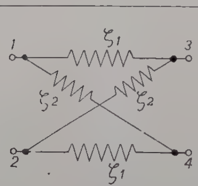
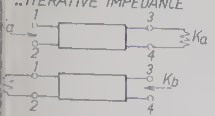
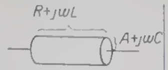
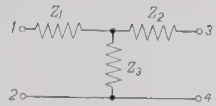
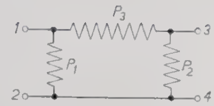
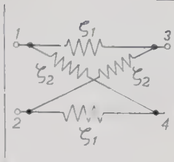
|  | $V_1 = \alpha V_2 + \beta I_2$<br>$I_1 = \gamma V_2 + \delta I_2$<br>$\alpha\delta - \beta\gamma = 1$ | <br>$\frac{Z_{ak}}{Z_{ao}} = \frac{Z_{bk}}{Z_{bo}} \left(= \frac{Z_k}{Z_o}\right)$ | „IMAGE IMPEDANCE"<br><br>$\frac{I_2}{I_1} = \sqrt{\frac{Z_a}{Z_b}}\, e^{-T}$ |
| $V_1 = \alpha V_2 + \beta I_2$<br>$I_1 = \gamma V_2 + \delta I_2$<br>$\alpha\delta - \beta\gamma = 1$ | | $\alpha = \sqrt{\frac{Z_{ao}}{Z_{bo}}}\ \frac{1}{\sqrt{1-\frac{Z_k}{Z_o}}}$<br>$\beta = \frac{\sqrt{Z_{ak}\ Z_{bk}}}{\sqrt{1-\frac{Z_k}{Z_o}}}$<br>$\gamma = \frac{1}{\sqrt{Z_{ao} Z_{bo}}}\ \frac{1}{\sqrt{1-\frac{Z_k}{Z_o}}}$<br>$\delta = \sqrt{\frac{Z_{bo}}{Z_{ao}}}\ \frac{1}{\sqrt{1-\frac{Z_k}{Z_o}}}$ | $\alpha = \sqrt{\frac{Z_a}{Z_b}}\ \cosh T$<br>$\beta = \sqrt{Z_a Z_b}\ \sinh T$<br>$\gamma = \frac{1}{\sqrt{Z_a Z_b}}\ \sinh T$<br>$\delta = \sqrt{\frac{Z_b}{Z_a}}\ \cosh T$ |
| <br>$\frac{Z_{ak}}{Z_{ao}} = \frac{Z_{bk}}{Z_{bo}} \left(= \frac{Z_k}{Z_o}\right)$ | $Z_{ao} = \frac{\alpha}{\gamma}$<br>$Z_{ak} = \frac{\beta}{\delta}$<br>$Z_{bo} = \frac{\delta}{\gamma}$<br>$Z_{bk} = \frac{\beta}{\alpha}$ | | $Z_{ao} = Z_a \coth T$<br>$Z_{ak} = Z_a \tanh T$<br>$Z_{bo} = Z_b \coth T$<br>$Z_{bk} = Z_b \tanh T$ |
| „IMAGE IMPEDANCE"<br><br>$\frac{I_2}{I_1} = \sqrt{\frac{Z_a}{Z_b}}\, e^{-T}$ | $Z_a = \sqrt{\frac{\alpha\beta}{\gamma\delta}}$<br>$Z_b = \sqrt{\frac{\beta\delta}{\alpha\gamma}}$<br>$\cosh T = \sqrt{\alpha\delta}$ | $Z_a = \sqrt{Z_{ao}\ Z_{ak}}$<br>$Z_b = \sqrt{Z_{bo}\ Z_{bk}}$<br>$\tanh T = \sqrt{\frac{Z_k}{Z_o}}$ | |
| „ITERATIVE IMPEDANCE"<br><br>$\frac{I_2}{I_1} = e^{-\Gamma}$ | $K_a = \frac{\sqrt{(\alpha+\delta)^2-4}+\alpha-\delta}{2\gamma}$<br>$K_b = \frac{\sqrt{(\alpha+\delta)^2-4}+\delta-\alpha}{2\gamma}$<br>$\cosh\Gamma = \frac{\alpha+\delta}{2}$ | $K_a = \frac{1}{2}(Z_{ao}-Z_{bo}) + \frac{1}{2}\sqrt{(Z_{ao}-Z_{bo})^2 + 4\ Z_{ao}\ Z_{bk}}$<br>$K_b = \frac{1}{2}(Z_{bo}-Z_{ao}) + \frac{1}{2}\sqrt{(Z_{ao}-Z_{bo})^2 + 4\ Z_{ao}\ Z_{bk}}$<br>$\cosh\Gamma = \frac{Z_{ao}+Z_{bo}}{2\sqrt{Z_{ao}\,(Z_{bo}-Z_{bk})}}$ | $K_a = \frac{1}{2}(Z_a-Z_b)\coth T + \frac{1}{2}\sqrt{(Z_a-Z_b)^2\coth^2 T + 4\, Z_a}$<br>$K_b = \frac{1}{2}(Z_b-Z_a)\coth T + \frac{1}{2}\sqrt{(Z_a-Z_b)^2\coth^2 T + 4\, Z_a}$<br>$\cosh\Gamma = \frac{1}{2}\left(\sqrt{\frac{Z_a}{Z_b}} + \sqrt{\frac{Z_b}{Z_a}}\right)\cosh T$ |
| <br>$Z = \sqrt{\frac{R+j\omega L}{A+j\omega C}}$<br>$\Gamma' = \sqrt{(R+j\omega L)(A+j\omega C)}$ | $R+j\omega L = \sqrt{\frac{\beta}{\gamma}}\ \text{arc}\cosh\alpha$<br>$A+j\omega C = \sqrt{\frac{\gamma}{\beta}}\ \text{arc}\cosh\alpha$ | $R+j\omega L = \sqrt{Z_o Z_k}\ \text{arc}\tanh\sqrt{\frac{Z_k}{Z_o}}$<br>$A+j\omega C = \frac{1}{\sqrt{Z_o Z_k}}\ \text{arc}\tanh\sqrt{\frac{Z_k}{Z_o}}$ | $R+j\omega L = Z\ T$<br>$A+j\omega C = \frac{T}{Z}$ |
|  | $Z_1 = \frac{\alpha-1}{\gamma}$<br>$Z_2 = \frac{\delta-1}{\gamma}$<br>$Z_3 = \frac{1}{\gamma}$ | $Z_1 = Z_{ao} - \sqrt{Z_{ao} Z_{bo}}\sqrt{1-\frac{Z_k}{Z_o}}$<br>$Z_2 = Z_{bo} - \sqrt{Z_{ao} Z_{bo}}\sqrt{1-\frac{Z_k}{Z_o}}$<br>$Z_3 = \sqrt{Z_{ao} Z_{bo}}\sqrt{1-\frac{Z_k}{Z_o}}$ | $Z_1 = \frac{Z_a\cosh T - \sqrt{Z_a Z_b}}{\sinh T}$<br>$Z_2 = \frac{Z_b\cosh T - \sqrt{Z_a Z_b}}{\sinh T}$<br>$Z_3 = \frac{\sqrt{Z_a\ Z_b}}{\sinh T}$ |
|  | $P_1 = \frac{\beta}{\delta-1}$<br>$P_2 = \frac{\beta}{\alpha-1}$<br>$P_3 = \beta$ | $P_1 = \frac{Z_{ak}}{1-\sqrt{\frac{Z_{ao}}{Z_{bo}}}\sqrt{1-\frac{Z_k}{Z_o}}}$<br>$P_2 = \frac{Z_{bk}}{1-\sqrt{\frac{Z_{bo}}{Z_{ao}}}\sqrt{1-\frac{Z_k}{Z_o}}}$<br>$P_3 = \frac{\sqrt{Z_{ak}\ Z_{bk}}}{\sqrt{1-\frac{Z_k}{Z_o}}}$ | $P_1 = \frac{Z_a\sinh T}{\cosh T - \sqrt{\frac{Z_a}{Z_b}}}$<br>$P_2 = \frac{Z_b\sinh T}{\cosh T - \sqrt{\frac{Z_b}{Z_a}}}$<br>$P_3 = \sqrt{Z_a Z_b}\ \sinh T$ |
|  | $\zeta_1 = \frac{\beta}{\alpha+1}$<br>$\zeta_2 = \frac{\beta}{\alpha-1}$ | $\zeta_1 = Z_o\left(1-\sqrt{1-\frac{Z_k}{Z_o}}\right)$<br>$\zeta_2 = \frac{Z_k}{1-\sqrt{1-\frac{Z_k}{Z_o}}}$ | $\zeta_1 = Z\ \tanh\frac{T}{2}$<br>$\zeta_2 = Z\ \coth\frac{T}{2}$ |

| „ITERATIVE IMPEDANCE"  $\frac{I_2}{I_1}=e^{-\Gamma}$ |   $Z=\sqrt{\frac{R+j\omega L}{A+j\omega C}}$<br>$\Gamma'=\sqrt{(R+j\omega L)(A+j\omega C)}$ |   |   |   |
|---|---|---|---|---|
| $\alpha=\frac{K_a e^{\Gamma}+K_b e^{-\Gamma}}{K_a+K_b}$<br>$\beta=\frac{2K_aK_b}{K_a+K_b}\sinh\Gamma$<br>$\gamma=\frac{2}{K_a+K_b}\sinh\Gamma$<br>$\delta=\frac{K_b e^{\Gamma}+K_a e^{-\Gamma}}{K_a+K_b}$ | $\alpha=\delta=\cosh\Gamma^1$<br>$\beta=Z\sinh\Gamma^1$<br>$\gamma=\frac{1}{Z}\sinh\Gamma^1$ | $\alpha=1+\frac{Z_1}{Z_3}$<br>$\beta=\frac{Z_1Z_2+Z_2Z_3+Z_3Z_1}{Z_3}$<br>$\gamma=\frac{1}{Z_3}$<br>$\delta=1+\frac{Z_2}{Z_3}$ | $\alpha=1+\frac{P_3}{P_2}$<br>$\beta=P_3$<br>$\gamma=\frac{P_1+P_2+P_3}{P_1P_2}$<br>$\delta=1+\frac{P_3}{P_1}$ | $\alpha=\delta=\frac{\zeta_2+\zeta_1}{\zeta_2-\zeta_1}$<br>$\beta=\frac{2\zeta_1\zeta_2}{\zeta_2-\zeta_1}$<br>$\gamma=\frac{2}{\zeta_2-\zeta_1}$ |
| $Z_{ao}=\frac{K_a e^{\Gamma}+K_b e^{-\Gamma}}{2\sinh\Gamma}$<br>$Z_{ak}=\frac{2K_aK_b\sinh\Gamma}{K_b e^{\Gamma}+K_a e^{-\Gamma}}$<br>$Z_{bo}=\frac{K_b e^{\Gamma}+K_a e^{-\Gamma}}{2\sinh\Gamma}$<br>$Z_{bk}=\frac{2K_aK_b\sinh\Gamma}{K_a e^{\Gamma}+K_b e^{-\Gamma}}$ | $Z_{ao}=Z_{bo}=Z\coth\Gamma^1$<br>$Z_{ak}=Z_{bk}=Z\tanh\Gamma^1$ | $Z_{ao}=Z_1+Z_3$<br>$Z_{ak}=\frac{Z_1Z_2+Z_2Z_3+Z_3Z_1}{Z_2+Z_3}$<br>$Z_{bo}=Z_2+Z_3$<br>$Z_{bk}=\frac{Z_1Z_2+Z_2Z_3+Z_3Z_1}{Z_1+Z_3}$ | $Z_{ao}=\frac{P_1(P_2+P_3)}{P_1+P_2+P_3}$<br>$Z_{ak}=\frac{P_1P_3}{P_1+P_3}$<br>$Z_{bo}=\frac{P_2(P_1+P_3)}{P_1+P_2+P_3}$<br>$Z_{bk}=\frac{P_2P_3}{P_2+P_3}$ | $Z_{ao}=Z_{bo}=\tfrac{1}{2}(\zeta_1+\zeta_2)$<br>$Z_{ak}=Z_{bk}=\frac{2\zeta_1\zeta_2}{\zeta_1+\zeta_2}$ |
| $Z_a=\sqrt{K_aK_b}\sqrt{\frac{K_a e^{\Gamma}+K_b e^{-\Gamma}}{K_b e^{\Gamma}+K_a e^{-\Gamma}}}$<br>$Z_b=\sqrt{K_aK_b}\sqrt{\frac{K_b e^{\Gamma}+K_a e^{-\Gamma}}{K_a e^{\Gamma}+K_b e^{-\Gamma}}}$<br>$\cosh T=\sqrt{\frac{4K_aK_b}{(K_a+K_b)^2}\cosh^2\Gamma+\left(\frac{K_a-K_b}{K_a+K_b}\right)^2}$ | $Z_a=Z_b=Z$<br>$T=\Gamma^1$ | $Z_a=\sqrt{\frac{(Z_1+Z_3)(Z_1Z_2+Z_2Z_3+Z_3Z_1)}{Z_2+Z_3}}$<br>$Z_b=\sqrt{\frac{(Z_2+Z_3)(Z_1Z_2+Z_2Z_3+Z_3Z_1)}{Z_1+Z_3}}$<br>$\cosh T=\frac{1}{Z_3}\sqrt{(Z_1+Z_3)(Z_2+Z_3)}$ | $Z_a=P_1\sqrt{\frac{P_3(P_2+P_3)}{(P_1+P_3)(P_1+P_2+P_3)}}$<br>$Z_b=P_2\sqrt{\frac{P_3(P_1+P_3)}{(P_2+P_3)(P_1+P_2+P_3)}}$<br>$\cosh T=\sqrt{\frac{(P_1+P_3)(P_2+P_3)}{P_1P_2}}$ | $Z_a=Z_b=\sqrt{\zeta_1\zeta_2}$<br>$\tanh\frac{T}{2}=\sqrt{\frac{\zeta_1}{\zeta_2}}$ |
| | $K_a=K_b=Z$<br>$\Gamma=\Gamma^1$ | $K_a=\tfrac{1}{2}(Z_1-Z_2)+\tfrac{1}{2}\sqrt{(Z_1+Z_2)^2+4Z_3(Z_1+Z_2)}$<br>$K_b=\tfrac{1}{2}(Z_2-Z_1)+\tfrac{1}{2}\sqrt{(Z_1+Z_2)^2+4Z_3(Z_1+Z_2)}$<br>$\cosh\Gamma=1+\frac{Z_1+Z_2}{2Z_3}$ | $K_a=\frac{P_3(P_1-P_2)+\sqrt{P_3^2(P_1+P_2)^2+4P_1P_2P_3(P_1+P_2)}}{2(P_1+P_2+P_3)}$<br>$K_b=\frac{P_3(P_2-P_1)+\sqrt{P_3^2(P_1+P_2)^2+4P_1P_2P_3(P_1+P_2)}}{2(P_1+P_2+P_3)}$<br>$\cosh\Gamma=1+\tfrac{1}{2}P_3\left(\frac{1}{P_1}+\frac{1}{P_2}\right)$ | $K_a=K_b=\sqrt{\zeta_1\zeta_2}$<br>$\tanh\frac{\Gamma}{2}=\sqrt{\frac{\zeta_1}{\zeta_2}}$ |
| $R+j\omega L=K\Gamma$<br>$A+j\omega C=\frac{\Gamma}{K}$ | | $R+j\omega L=\sqrt{Z_1^2+2Z_1Z_3}\ \mathrm{arc}\cosh\left(1+\frac{Z_1}{Z_3}\right)$<br>$A+j\omega C=\frac{1}{\sqrt{Z_1^2+2Z_1Z_3}}\ \mathrm{arc}\cosh\left(1+\frac{Z_1}{Z_3}\right)$ | $R+j\omega L=P_1\sqrt{\frac{P_3}{2P_1+P_3}}\ \mathrm{arc}\cosh\left(1+\frac{P_3}{P_1}\right)$<br>$A+j\omega C=\frac{1}{P_1}\sqrt{\frac{2P_1+P_3}{P_3}}\ \mathrm{arc}\cosh\left(1+\frac{P_3}{P_1}\right)$ | $R+j\omega L=2\sqrt{\zeta_1\zeta_2}\ \mathrm{arc}\tanh\sqrt{\frac{\zeta_1}{\zeta_2}}$<br>$A+j\omega C=\frac{2}{\sqrt{\zeta_1\zeta_2}}\ \mathrm{arc}\tanh\sqrt{\frac{\zeta_1}{\zeta_2}}$ |
| $Z_1=\frac{K_a-K_b e^{-\Gamma}}{1+e^{-\Gamma}}$<br>$Z_2=\frac{K_b-K_a e^{-\Gamma}}{1+e^{-\Gamma}}$<br>$Z_3=\frac{K_a+K_b}{2\sinh\Gamma}$ | $Z_1=Z_2=Z\tanh\frac{\Gamma^1}{2}$<br>$Z_3=\frac{Z}{\sinh\Gamma^1}$ | | $Z_1=\frac{P_1P_3}{P_1+P_2+P_3}$<br>$Z_2=\frac{P_2P_3}{P_1+P_2+P_3}$<br>$Z_3=\frac{P_1P_2}{P_1+P_2+P_3}$ | $Z_1=Z_2=\zeta_1$<br>$Z_3=\tfrac{1}{2}(\zeta_2-\zeta_1)$ |
| $P_1=\frac{K_aK_b(1+e^{-\Gamma})}{K_b-K_a e^{-\Gamma}}$<br>$P_2=\frac{K_aK_b(1+e^{-\Gamma})}{K_a-K_b e^{-\Gamma}}$<br>$P_3=\frac{2K_aK_b\sinh\Gamma}{K_a+K_b}$ | $P_1=P_2=Z\coth\frac{\Gamma^1}{2}$<br>$P_3=Z\sinh\Gamma^1$ | $P_1=\frac{Z_1Z_2+Z_2Z_3+Z_3Z_1}{Z_2}$<br>$P_2=\frac{Z_1Z_2+Z_2Z_3+Z_3Z_1}{Z_1}$<br>$P_3=\frac{Z_1Z_2+Z_2Z_3+Z_3Z_1}{Z_3}$ | | $P_1=P_2=\zeta_2$<br>$P_3=\frac{2\zeta_1\zeta_2}{\zeta_2-\zeta_1}$ |
| $\zeta_1=K\tanh\frac{\Gamma}{2}$<br>$\zeta_2=K\coth\frac{\Gamma}{2}$ | $\zeta_1=Z\tanh\frac{\Gamma^1}{2}$<br>$\zeta_2=Z\coth\frac{\Gamma^1}{2}$ | $\zeta_1=Z_1$<br>$\zeta_2=Z_1+2Z_3$ | $\zeta_1=\frac{P_1P_3}{2P_1+P_3}$<br>$\zeta_2=P_1$ | |

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general quadripole is thus determined by six elements.

The quadripoles such as are represented by filters are, however, of a special type. We are here only interested in the voltages between the primary poles 1 and 2 on the one hand and between the secondary poles 3 and 4 on the other. Outside of the filter there is no electrical connection between the pair of terminals 1 and 2 and the pair 3 and 4 (*fig. 2*).

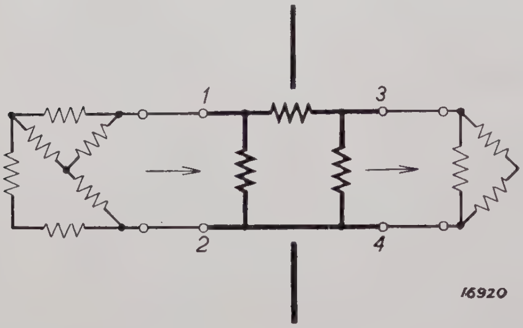


Fig. 2. Di-dipole, a special form of quadripole, which is defined by only three impedances, where the four external terminals *1*, *2*, *3* and *4* are divided into two primaries *1* and *2* and two secondaries *3* and *4*. Externally to the di-dipole there is no electrical connection between the primary terminals on the one hand and the secondary terminals on the other.

It may be shown that, owing to these restrictions, applied to the general quadripole and which reduce the latter to a di-dipole, only three impedances are required for defining the characteristics of the network.

**Various Ways of Defining a Filter by Three Parameters**

The three impedances which are sufficient for defining a filter can be regarded as distributed in a quadripole in various ways, the different configurations being mutually transformable without the external characteristics of the filter being altered in any way. If the filter is symmetrical, i.e. if the external currents and voltages remain unaltered, when the primary terminals are made the secondary terminals and the secondary the primary, two impedances will be sufficient for defining the filter. In the large table on pp. 242 and 243 the three determinant impedances (for symmetrical filters, two impedances) are represented in various ways, together with the conversion formulae for transformation from one system of variables to another. In place of three determinant impedances three other mutually independent parameters can also be used, or also four parameters with one interrelation.

In the table each filter is defined in succession by:

a) the four coefficients of its analytical expression:

$$\begin{cases} V_1 = \alpha V_2 + \beta I_2 \\ I_1 = \gamma V_2 + \delta I_2 \end{cases}$$

in which the four coefficients $\alpha$, $\beta$, $\gamma$ and $\delta$ are connected by the expression:

$$\alpha\,\delta - \beta\,\gamma = 1$$

b) the primary input impedance $Z_{ao}$ with the secondary terminals open-circuited, the primary input impedance $Z_{ak}$ with the secondary terminals short circuited, the secondary input impedance $Z_{bo}$ with the primary terminals open circuited and the secondary input impedance $Z_{bk}$ with the primary impedances, where these four terminals short circuited are interrelated as follows:

$$Z_{ak}/Z_{ao} = Z_{bk}/Z_{bo}\,;$$

c) the primary image impedance $Z_a$, the secondary image impedance $Z_b$ and the propagation constant $T$, being defined as follows: If the secondary side is terminated in an external impedance $Z_b'$, then the impedance between the primary terminals is $Z_a$; if the primary side is terminated in an external impedance $Z_a'$, leaving the secondary terminals open-circuited, then the impedance between the secondary terminals is $Z_b$. If the values of $Z_a'$ and $Z_b'$ are so chosen that $Z_a = Z_a'$ and $Z_b = Z_b'$ then $Z_a$ and $Z_b$ are termed the primary and secondary image impedances. The propagation constant is then defined as:

$$\frac{I_2}{I_1} = \sqrt{\frac{Z_a}{Z_b}}\, e^{-T}\,;$$

d) the primary iterative impedance $K_a$, the secondary iterative impedance $K_b$ and the propagation constant $\Gamma$, being defined as follows: On shorting the secondary side with an impedance $K_a$ the filter when seen from the primary side, similarly has the impedance $K_a$; on shorting the primary side through an impedance $K_b$, the filter similarly has an impedance $K_b$ as seen from the secondary side. These impedances $K_a$ and $K_b$ are termed the primary and secondary iterative impedances; the propagation constant $\Gamma$ is then defined as:

$$\frac{I_2}{I_1} = e^{-\Gamma},$$

(this propagation constant $\Gamma$ is only equal, to the propagation constant referred to under c in the case of a symmetrical filter);

e) cable defined by its impedance $R + j\omega L$ and its parallel admittance $A + j\omega C$;

f) a network in the form of a $T$ with the three impedances $Z_1$, $Z_2$ and $Z_3$;

g) a network in the form of a $\Pi$ with the three impedances $P_1$, $P_2$ and $P_3$;

h) a symmetrical lattice network with the two impedances $\zeta_1$ and $\zeta_2$, each occurring twice (this circuit corresponds to an ordinary bridge circuit, *fig.* 3).

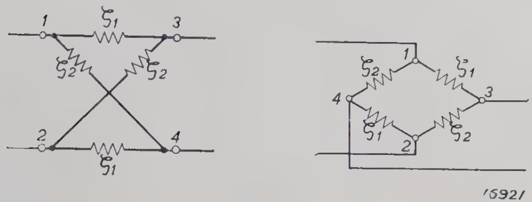


Fig. 3. Two methods of representing the same di-dipole; a symmetrical lattice network and a bridge circuit.

It should be noted that definitions *e*) and *h*) apply only to a symmetrical filter; the other definitions are based on an unsymmetrical filter, but become simplified when applied to a symmetrical filter. Thus for a symmetrical filter $a = \delta$; $Z_{ak} = Z_{bk}$; $Z_{ao} = Z_{bo}$; $Z_a = Z_b$; $K_a = K_b$; $Z_1 = Z_2$; $P_1 = P_2$.

As already indicated, any arbitrary filter can be regarded as compounded in any one of the ways *a*), *b*), *c*), *d*), *e*), *f*), *g*) and *h*), where *e*) and *h*) apply to symmetrical filters only, and in place of a filter, it is thus possible to substitute that network which will be the simplest for the particular case under consideration. In principle all networks given are equivalent and the table enables each method of representation to be transformed to any other. On transformation to another frequency independent calculation should in general be carried out, as impedances are usually obtained whose frequency dependence cannot be realised in practice.

The general characteristics found are employed in the solution of practical problems relating to the construction of high-pass, low-pass or band-pass filters to meet specific requirements, a subject to be discussed in subsequent lectures.

# THE COMMUNAL AERIAL

By J. VAN SLOOTEN.

**Summary.** This article describes the electrical construction and method of operation of the aerial-signal amplifier "Antennaphil". With this apparatus it is possible, to supply aerial signals to a large number of receiving sets in a block of flats by using a single aerial only. Aerial-signal amplification also eliminates interference in reception.

## Introduction

In large towns and cities the provision of a good aerial is usually fraught with serious difficulties, particularly in houses divided up into self-contained flats. As a rule it is not an easy matter to erect on one and the same roof a large number of separate aerials which would satisfy the requirements of all listeners. There is also the additional difficulty that in some places radio reception is practically impossible owing to interference from electric motors and other apparatus.

To surmount these difficulties a communal aerial system was evolved some years ago in these Laboratories and marketed under the name of the "Antennaphil". Briefly, this system operates in the following manner: An aerial of suitable dimensions and quality is erected at a point where interference is limited, e.g. 20 ft. above the roof. Through a specially-screened lead-in, which is made as short as possible, the aerial is connected to a so-called aerial-signal amplifier from which the incoming signals are transmitted to a number of receiving sets through a screened distributing circuit (lead-covered cable). As a rule up to 50 sets can be connected to an aerial fitted with this form of amplifier. The arrangement can also be employed quite satisfactorily with a smaller number of sets where reception sufficiently free from interference can only be obtained at a distance of several hundred to a thousand yards. These Laboratories have had an aerial of this type in use for several years in order to ensure reception free from all interference. The aerial and the aerial-signal amplifier are located about 200 yards from the laboratory on a building estate, and the supply cable for the amplifier and the high-frequency distribution cable from the amplifier are laid underground.

The amplifier consists essentially of:

a) an electrical filter unit,
b) a number of amplifying valves (high-frequency pentodes) and
c) two output transformers for matching the valves to the distribution cable.

In addition to the characteristics of the amplifier, those of the high-frequency distributing cable are also important, and as these closely determine the operation and design of the amplifier a brief discussion of the cable characteristics will not be out of place here.

## The High-Frequency Distributing Cable

For the present purpose the best type of cable to use is a coaxial or concentric high-frequency cable, a diagrammatic section of which is shown

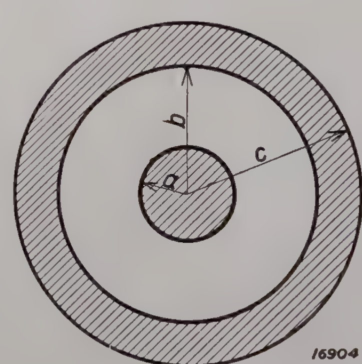


Fig. 1. Section through a high-frequency cable. $a$ — Radius of core, $b$ and $c$ — internal and external radius of sheath. For a specific value of $b/a$ the attenuation of the cable is a minimum. With a copper core and a lead sheath $b/a$ must for instance be 5.2.

in *fig. 1*. The diameter of the core is $2a$ and the internal diameter of the sheath $2b$, the external $2c$.

The intervening space is usually filled with a dielectric (paper or rubber), but may also have a partial air space. This insulating medium can be characterised by two constants, the dielectric constant $\varepsilon$ and the phase difference $\delta$. The tangent of the phase difference is given by the ratio of the effective current to the capacity current (per unit of length) and with air as dielectric is nearly unity. In cables with a good quality paper or rubber insulation $\delta$ is 0.01 to 0.025. Over the range of radio wave lengths $\delta$ is practically independent of the frequency. In addition to the sectional linear dimensions of the cable, this phase difference also determines the attenuation sustained by the oscillations during their passage through the cable.

The principal factor governing the practical efficiency of the cable is the so-called *characteristic impedance*. A remarkable property of a homogeneous cable is that its impedance measured at the input terminals tends towards a specific limiting resistance (the characteristic impedance) when the cable is made infinitely long. If the frequency is made sufficiently high, this resistance is practically independent of the frequency.

It follows from this property of an *infinitely long cable* that the input impedance of a finite cable will also become equal to the characteristic impedance if the resistance of the load at the output terminals is equal to the characteristic impedance; for in this way the same effect is produced as is obtained by prolonging the cable with an infinite length of equivalent cable. Under these circumstances no reflection therefore occurs at the ends and a true progressive wave is produced. This is the result desired, since the reflected wave travelling in the opposite direction may interfere with the advancing wave and thus generate nodes and antinodes in the voltage, which would prove very disturbing. With this type of disturbance an inadequate signal voltage would be obtained in any receiver connected to a nodal point of the cable. It is apparent from the above considerations that the cable must be a straight-through conductor without any taps or branches.

When designing the distributing system the first point to be considered is the choice of the optimum characteristics of the cable. The characteristic impedance should be fairly low, e.g. 60 ohms, for the cable is also loaded with the input impedances of the connected receivers. Hence, by using a cable with a high characteristic impedance the voltage distribution through the cable would be subject to serious interference. Another consideration also indicates the need for a low characteristic impedance. The question must be raised as to what must be the core thickness in a cable with a given thickness of lead sheathing (as determined, for instance, by cost considerations) in order to obtain the lowest possible drop in amplitude per unit length of the cable.

With a lead sheath and a copper core we get for the ratio of $b$ to $a$ (see fig. 1):

$$\frac{b}{a} \quad 5.2 \quad \ldots\ldots\ldots \quad (1)$$

and for this ratio the characteristic impedance is similarly of the order of 60 ohms [1]), independently of the absolute value of the diameter.

Having determined the value of this ratio, we can also calculate the lowest absolute values for these diameters. The attenuation losses in the cable can be resolved into the copper losses in the insulation, which are determined by the ohmic resistances of the core and the sheath, taking into consideration the skin effect and the dielectric losses in the insulation, which are proportional to the phase difference already referred to. The latter damping effect is determined solely by the insulating material and is independent of $a$ and $b$.

Analysis of the copper losses gives equation (1); these losses can also be reduced as required by increasing the cross-section of the cable, but this is naturally of use only as long as the dielectric losses do not predominate [2]).

A practical example is, for instance, the following cable in which the attenuation due to the copper losses is equal to that due to the dielectric losses at a wave length of 200 m.

$$2a = 2.5 \text{ mm}, \; 2b = 13 \text{ mm}, \; \varepsilon = 2.5;$$
$$\delta = 0.02, \; Z = 63 \text{ ohms}.$$

With a wave length of 200 m this cable produced an overall attenuation of 1 neper, i.e. a transmission loss factor of 2.72 per km. With higher

[1]) The exact formula is:

$$\ln\frac{b}{a} = 1 + \frac{a}{b}\sqrt{\frac{\varrho_2}{\varrho_1}} \quad , \ldots\ldots \quad (1a)$$

where $\varrho_2$ and $\varrho_1$ are the specific resistances of the materials of the sheath and the core. The relationship between the characteristic impedance Z, the values $a$, $b$ and the dielectric constant $\varepsilon$ of the insulating material is:

$$Z = \frac{60}{\sqrt{\varepsilon}} \ln\frac{b}{a} \text{ Ohm} \quad \ldots\ldots\ldots \quad (2)$$

If e.g. we put $\varepsilon = 2.5$ and take $\frac{b}{a}$ from equation (1), we get Z = 63 ohms.

[2]) For further details and the derivation of equation (1a) see Radio-Nieuws, **17**, 77, 1934.

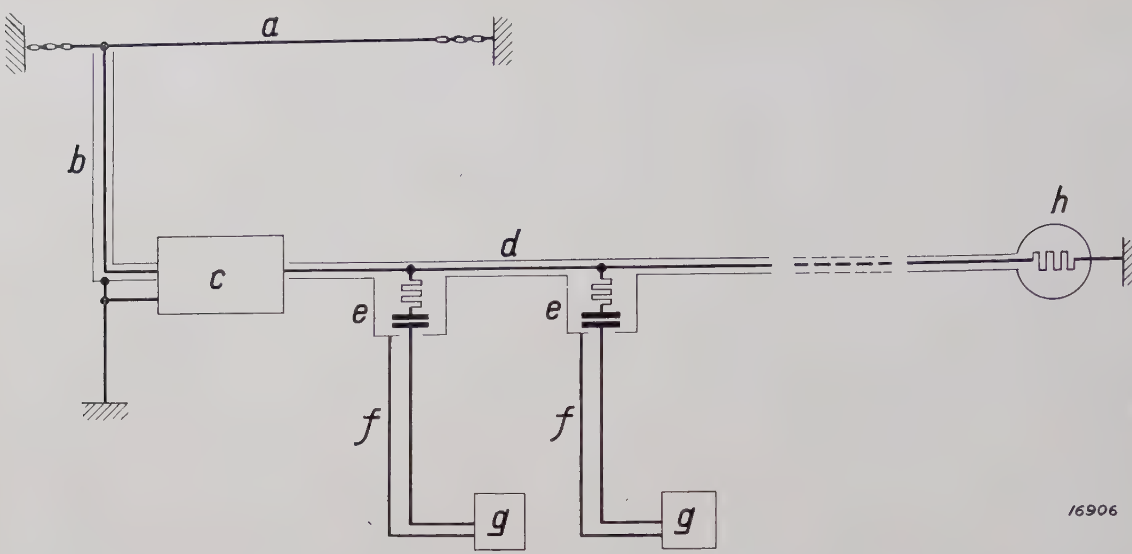


Fig. 2. General view of the aerial distributing system. *a* — aerial, *b* — lead in, *c* — aerial-signal amplifier, *d* — high-frequency distributing cable, *e* — branch boxes, *f* — lead, *g* — receiving set, *h* — terminating resistance.

wave lengths the attenuation diminishes, whilst with shorter wave lengths it increases; in the latter case dielectric losses also predominate.

Actually this cable is more than adequate for the purpose intended. For a receiving system where the cable is not more than 200 to 300 yards long a much thinner cable could also be employed with still satisfactory results, and it is then also possible to use one of the many low-capacity cables, which in general have a characteristic impedance of 100 to 150 ohms, for the screened aerial lead-in.

*Fig. 2* gives a general view of the receiving system, where *a* is the aerial, *b* the aerial lead-in for which a screened low-capacity should be used for preference, *c* is the aerial-signal amplifier, and *d* the high-frequency distributing cable. The phantom aerials for eliminating the effect of the cable on the tuning of the receiver and which consist of a 200 μμF condenser and a 30-ohm resistance connected in series are accommodated in the branch boxes *e* inserted in the cable. To connect a branch box to a receiver *g* a flexible screened cable *f* with a low capacity not exceeding 40 μμF per metre and not more than 3 to 4 yards long should be used. The earthing terminal of the receiver is connected directly to the cable sheath and is not separately earthed. A box with a terminal resistance *h* is located at the end of the cable, through which the sheath is earthed.

## The Aerial-Signal Amplifier

A simplified circuit diagram of an aerial-signal amplifier is given in *fig. 3*. The aerial voltages are passed to the grid of an amplifying valve (preferably a tetrode or pentode), the anode of this valve being connected to the cable impedance $Z$ through an output transformer $T$. As the valve has a high internal resistance and the impedance of the cable is low, it is necessary to step down $n$ times through $T$.

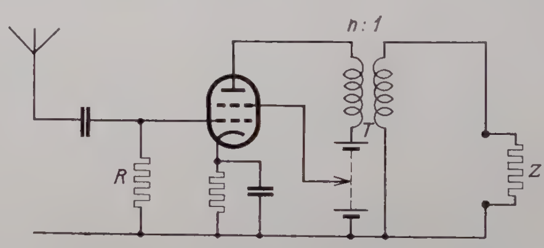


Fig. 3. Simplified circuit of an aerial-signal amplifier. The alternating voltages generated at the resistance $R$ are amplified and passed to the distributing cable $Z$ through a transformer $T$, which serves for matching the characteristic impedance of the cable to the valve.

Closer investigation indicates, however, that a simple amplifier of this type is unsuitable for transmitting a wide frequency sweep. The principal reason for this is the limitation sustained in the frequency as a result of the adverse capacity connected through the primary winding. This undesirable capacity is principally made up of the capacities of the valve and leads and the self-capacity of the winding.

The explanatory circuit in *fig. 4* shows how the voltage $E_1$ is produced through the primary winding of the transformer. The valve has been replaced by the current source $V_gS$ ($S$ = slope, $V_g$ = grid alternating voltage); $C_1$ represents the total undesirable capacity, $L_1$ is the self-induction of the primary winding and $n^2Z$ the secondary load resistance

transformed on to the primary side. The secondary output voltage is $n$ times smaller than $E_1$.

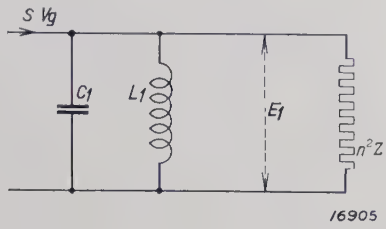


Fig. 4. Explanatory circuit for the circuit shown in fig. 3. $L_1$ — primary self-induction of the output transformer $T$, $C_1$ — adverse capacity. The current source $s\,V_g$ takes the place of the amplified aerial voltage and the impedance $n^2Z$ is in place of the transformed load resistance. At very low frequencies the alternating current is removed through $L_1$ and at very high frequencies through $C_1$. A maximum amplification is obtained at $\omega^2 L_1 C_1 = 1$.

It may be seen from *fig. 4* that in the absence of $C_1$ and with a sufficiently high self-induction $L_1$ the primary impedance is determined by $n^2Z$, and would require a high ratio of transformation $n$. This also applies when $C_1$ is present and is of sufficiently low rating, or when the circuit $L — C_1$ is in resonance with the incoming wave. But if $C_1$ becomes so great that its impedance determines the voltage $E_1$, the highest cable voltage is obtained with a low ratio of transformation $n$. Thus, $C_1$ determines the ratio which must be employed and with a higher wave length will be greater than with a short one, as the impedance of $C_1$ increases with the wave length.

The following conclusions may therefore be drawn:

1) The adverse influence of the undesirable capacity increases as the wave length is reduced.
2) The smaller the wave range to be amplified, the better can use be made of a resonance between the primary capacity $C_1$ and the self-induction $L_1$ for eliminating the adverse effect of $C_1$.
3) It is therefore advantageous not to amplify the whole wave range through a single amplifier and output transformer but to divide it up and amplify the components separately in parallel amplifying stages, whose output voltages can again be combined. In practice the wave range is divided into two components: the broadcasting range with wave lengths from 200 to 2000 m and the short-wave range from 20 to 55 m.

*Fig. 5* gives a view and *fig. 6* circuit details of the aerial-signal amplifier. On the right are two valves *III* and *IV* in parallel for amplifying the broadcast wave range, and further to the left two valves *I* and *II* for amplifying the short-wave

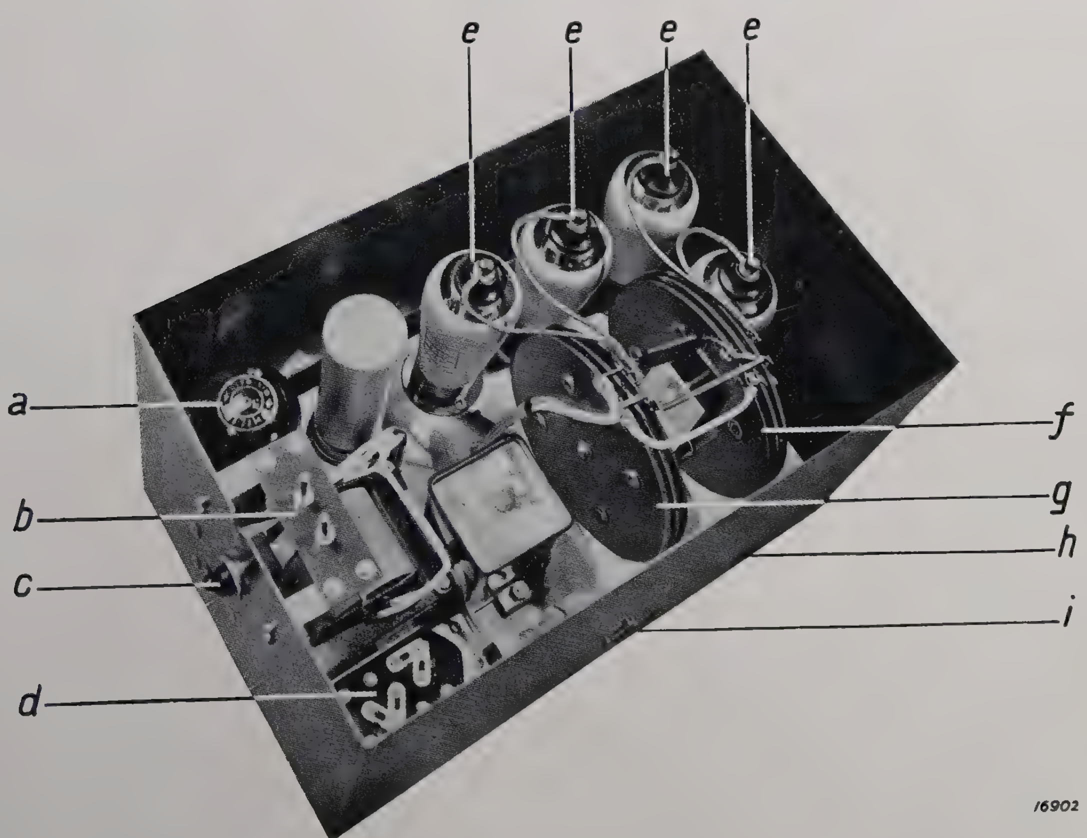


Fig. 5. View of the amplifier, open, showing the rectifying valve for the feed circuit ($a$), the mains connection ($b$), the mains switch ($c$), the change-over panel ($f$) for adjustment to various mains voltages, the amplifying valves ($e$), the two output transformers ($f$ and $g$) and the connections for the aerial and the distributing cable ($h$ and $i$).

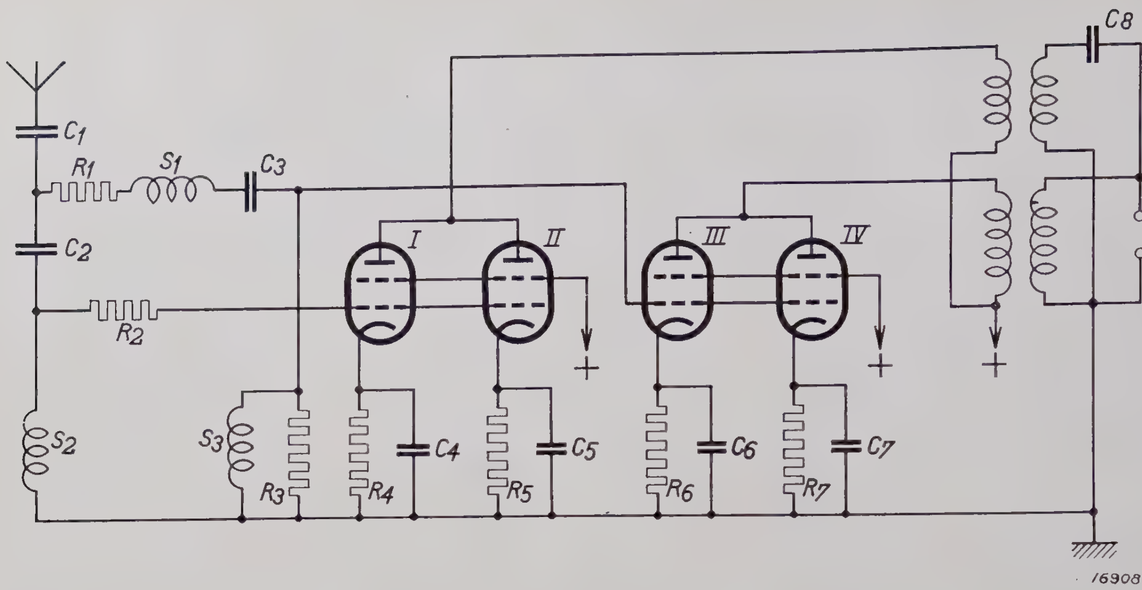


Fig. 6. Circuit cable of the aerial-signal amplifier. The valves *I* and *II* amplify the short waves and valves *III* and *IV* the broadcast waves. The circuit components $C_1$, $C_2$, $C_3$, $S_1$, $S_2$, $S_3$, $R_1$, $R_2$, $R_3$, constitute the filters for the two wave-length ranges. $C_8$ prevents the winding of the short-wave transformer from shorting the broadcast-wave transformer[3]).

range. The secondary windings of the two output transformers are connected to the input terminals of the cable. The condenser $C_8$ is necessary here to prevent the secondary winding of the transformer for the short-wave range from shorting the winding of the broadcast-range transformer with which it is in parallel.

On the left of fig. 6 there are a number of condensers, coils and resistances, which are inserted between the aerial and the grid of the amplifying valves. The main purpose of these units is to allow only those frequencies to pass to the valve grids which are to be amplified, for owing to the curved characteristic of the valve (anode current plotted against grid volts) it is possible for disturbing oscillations to be generated in the valve with frequencies which are the sum or difference of the frequencies passed to the grid. The risk of this interference materialising is considerably reduced if unnecessary frequencies are prevented from reaching the valve grids.

The units inserted between the aerial and the grids constitute a filter system which may be regarded as a combination of the simple filters shown in *figs.* 7 and 8. The filter in fig. 7 allows low frequencies to pass, and that in fig. 8 high frequencies. The limiting frequency is given in both cases by $\omega_0^2 L C = 1$ ($\omega = 2\pi f$, where $f$ is the frequency). The resistances $R$ serve for suppressing the peaks in the neighbourhood of a frequency of $\omega_0$. In both figures *I* is the transmission curve with a low resistance $R$, and *II* the transmission curve for a high resistance.

The various circuit components in fig. 6 serve the following purposes: $C_2$ and $S_2$ prevent wave lengths exceeding 55 m from reaching the grids of valves *I* and *II*. The input capacity of these valves is in parallel to $S_2$, so that resistance $R_2$ is required to suppress any disturbing resonance.

$S_1$ and the input capacity of valves *III* and *IV* prevent wave lengths of less than 200 m being impressed on the grids of these valves. Finally, $C_3$ and $S_3$ prevent wave lengths of over 2000 m reaching the grids of valves *III* and *IV*.

$R_1$ and $R_3$ are damping resistances which are so rated that the resonance peak is not entirely suppressed with wave lengths between 200 and 2000 m.

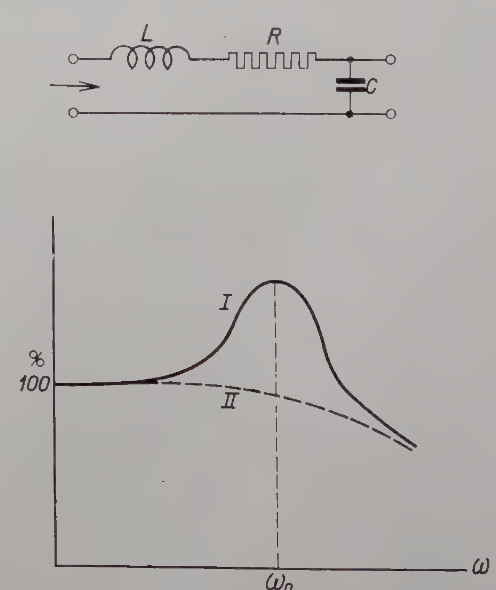


Fig. 7. A filter which suppresses frequencies above a limiting frequency of $\omega_0/2\pi$ (low-pass filter).

[3]) The latest design also contains two filter circuits, which suppress interference from any powerful local transmitting stations. To simplify the circuit diagram these have not been included here.

In *fig. 9* the aerial voltage furnished by the amplifier to a load of a resistance of 50 ohms is plotted against the wave length. The graph shows the subdivision into a short wave range and a broadcast wave range, which are obtained with resonance peaks partially smoothed by resistances. The resonance peaks *2* and *5* are due to filters of the type shown in fig. 8; peak *3* is due to a filter of the type shown in fig. 7, whilst peaks *1* and *4* correspond to resonance frequencies of the output transformers for the short-wave and broadcast-wave ranges.

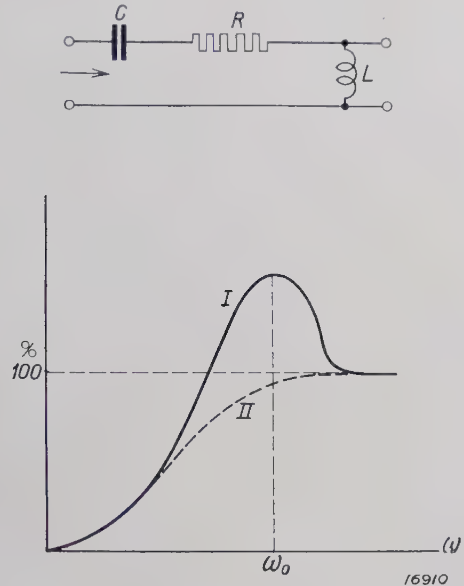


Fig. 8. A filter which suppresses frequencies below a certain limiting frequency $\omega_0/2\pi$ (high-pass filter). The limiting frequency is determined by $\omega_0^2 LC = 1$. Figs. 7 and 8 also show the transmission curves for the two filters: *I* for a low resistance *R* and *II* for a high resistance *R*.

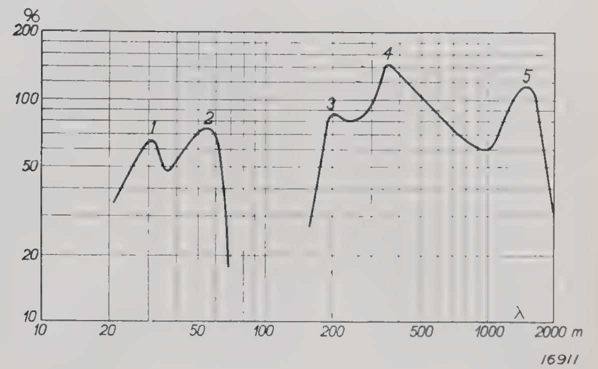


Fig. 9. Aerial voltage at a resistance of 50 ohms plotted against the wavelength. The peaks *2* and *5* are due to the high-pass filter and *3* to a low-pass filter; *1* and *4* are the resonance frequencies of the output transformers.

# SHORT NOTICES

## Sodium lighting of tennis courts

The problem of lighting tennis courts is of special interest as two requirements in particular have to be satisfied which, although also of importance in all illumination problems, yet have a special significance in this case; these are complete freedom from glare and high speed of discrimination. Both these requirements are exceptionally well fulfilled by a lighting system employing sodium lamps. As regards the danger of glare, experience has shown that the presence of a source of light in the field of vision is less disturbing with sodium lamps than with other light-sources of an equivalent total candle power. This fact is obviously due to the comparatively low luminous density of sodium lamps, although no satisfactory agreement has yet been obtained in the various attempts to arrive at quantitative determination of the disturbing effect of the glare produced with different types of light. With reference to the second factor, viz, high speed of discrimination, Arndt, Bouma, and Luckiesh and Moss established almost simultaneously that — as was recently confirmed by Weigel — the speed of discriminating objects is greater with sodium light than with other types of light. The speed of discrimination is defined as the time during which an observer must view an object in order to be able to recognise a specific detail of it with more than fifty per cent certainty. A similar task has to be performed by tennis players, who must be able to detect the exact location of the ball during its rapid flight.

Modern sodium lamps thus give a very satisfactory solution to the problem of illuminating tennis courts. As the glare factor is small, the lamps can be given a wide angle of radiation, and as a result uniform illumination is obtained even when the lamps are suspended at a low level, a low mounting height being desirable in order to obtain intensive illumination at a minimum of cost.

The illumination of tennis courts is particularly important in regions with a tropical climate where the heat renders play during the day impossible, and where during the evening, when the atmosphere is cooler, darkness sets in very quickly. Three open-air tennis courts in the Netherlands East Indies were recently equipped with sodium lamps, viz, one at Banjermasin and two at Sourabaya. Good results have been obtained in this case with an arrangement of eight sodium lamps ("Philora" SO, 150 watts) in two rows on both sides of the courts. These lamps are situated 20 ft. above the ground. Since little experience is as yet available of this special lighting problem it is possible that a still better arrangement of the lamps may yet be evolved (e.g. more lamps placed closer together). *Fig. 1* shows the suspension of the lamps and *fig. 2* an illuminated tennis court.

Fig. 1. Lighting fixtures of tennis courts with sodium lamps illuminated.

Fig. 2. Tennis court with sodium illumination.

# PRACTICAL APPLICATIONS OF X-RAYS FOR THE EXAMINATION OF MATERIALS VII

By W. G. BURGERS.

The X-ray photographs, obtained with mixed crystals (solid solutions), which were described in the previous article in this series, can frequently be utilised for the "indirect" detection by radiographic means of an admixture in a specific compound. In many cases the principal constituent is able, to take up an impurity in "solid solution", in other words the admixed body is not present as a separate phase, but forms a mixed crystal or solid solution with the chief substance present. This behaviour is observed, not only with substances having a similar crystal structure, i.e. with the formation of isomorphous crystals, but also with bodies which crystallize in entirely different systems and even when one of the components is a gas. The mixed crystal then assumes the crystalline form of the predominating component.

As was indicated in the previous article (VI), this phenomenon becomes apparent in X-ray analysis by a displacement of the interference lines for the principal component, such displacement being exhibited by a greater or lesser angle of deviation of the dispersed X-rays from the direction of the incident beam, according as the crystal lattice of the principal component is either "expanded" or "contracted" by the admixture. Although the impurity is not necessarily detected by this means and cannot therefore be identified, it is yet possible to establish that the principal product is not entirely pure, which in many cases is already of great importance. The two following examples illustrate these points.

Examination of the radiographs of the series of copper-nickel mixed crystals reproduced in fig. 1 of the previous article will show that the inner lines have suffered much greater mutual displacement than the outer lines. This striking effect is due to the method used in making the photographs. The "sensitivity" of the angle of diffraction to a change in the interatomic distances is in fact greatest for those lines produced by rays, which are deflected to the greatest extent from the direction of the incident radiation. These lines are situated at the two ends of the film in a "normal" exposure, where the film is so fixed in the camera, that the undeflected X-ray, on leaving the camera, passes through a hole in the middle of the film (cf. *fig. 1a*; see also fig. 2 of article I in this series, Philips techn. Rev. **1**, 29 1936). Better results are obtained when the film is placed in the camera in the manner described by van Arkel [1]), so that the X-ray passes through a hole in the film, not on leaving but on entering the camera (see *fig. 1b*): With such a

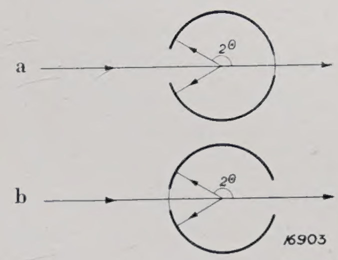


Fig. 1a. Normal position of film. The "sensitive" lines ($2\,\Theta$ slightly smaller than 180 deg.) are situated at the ends of the film.
b. "Reversed" film. The "sensitive" lines are at the middle, giving the advantage, that the measurement of the distances of the sensitive lines is less affected by shrinkage of the film during drying.

„reversed" film the „sensitive" lines are situated at the middle, which has the advantage, that the accuracy in measuring the interatomic distances for the sensitive lines is less affected by the shrinking of the film during drying. *Fig.* 2 again shows

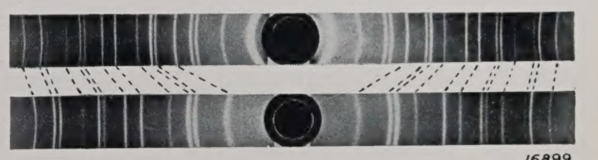


Fig. 2. "Reversed" X-ray photographs of isomorphous crystalline preparations.
a) Thorium oxide, $ThO_2$
b) Metallic thorium, Th.
Corresponding lines on both diagrams are connected with each other. It is clearly shown that the inner lines have undergone much greater mutual displacement than the outer lines.

clearly the marked difference in displacement between the inner and outer lines. The top exposure was obtained with thorium oxide $Th0_2$, and the lower one with metallic thorium these two bodies being "isomorphous", as regards the mutual arrangement of the thorium atoms, except that the distance between the Th atoms is much greater in the oxide than in the metal.

## 15. Excessive Tantalum Content of Tantalum Carbide [2])

It was stated in example 9 (article V, Philips techn. Rev. **1**, 188, 1936) that in the preparation of carbides of highly refractory metals the isolation of the metal itself sometimes takes place.

[1]) A. E. van Arkel, Z. Kristallogr. **67**, 235, 1928.

[2]) W. G. Burgers and J. C. M. Basart, Z. anorg. allg. Chem., **216**, 223, 1924.

The radiographs of certain filaments of zirconium carbide thus contain, in addition to lines due to the carbide itself, also those due to metallic zirconium (loc. cit. fig. 1). In these cases the metal has at least partially become separated in the free state as an independent phase alongside the carbide.

In making filaments of tantalum carbide the same phenomenon has been sometimes observed, whilst other wires were obtained which gave a pattern of only the carbide lines. These wires, which appeared identical on examination with the naked eye (having a light to golden yellow metallic lustre), could, however, be distinguished when strongly heated *in vacuo*, a behaviour which was naturally carefully observed in view of their possible use as incandescent filaments for lamps: Even at comparatively low temperatures (about 2000 °C.) the variation in resistance was found to differ from wire to wire and the bulbs became covered with a metallic mirror which differed in thickness from case to case. It was concluded from ("reversed") radiographs of the wires that the diameter of the inner interference line was different for each wire, corresponding to alterations in the interatomic distance of about 1 per cent. Two exposures illustrating this are shown in figs. *3a* and *b* [3]). It appeared

a

b

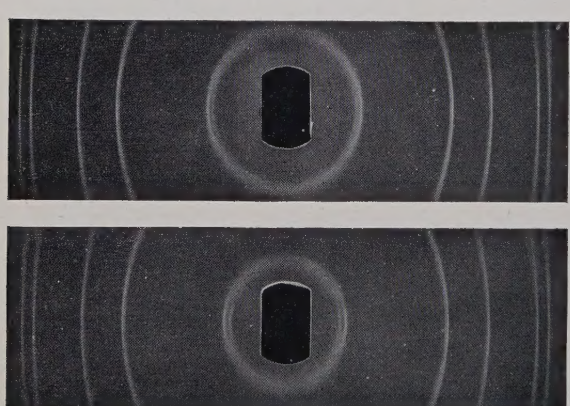

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Fig. 3. X-ray photographs of:
a) Pure tantalum carbide, Ta C
b) Tantalum carbide containing excess of tantalum in solid solution.
The inner ("sensitive") interference ring has a much smaller diameter in fig. b) than in fig. a).

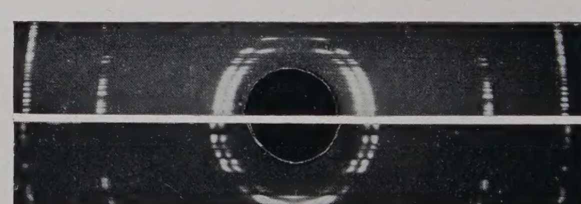
very probable that the wires had absorbed in solid solution different amounts of metallic tantalum in excess, an assumption which was subsequently confirmed for several wires by chemical (combustion) analysis, which gave a molecular composition corresponding to Ta : C = 6 : 5. By heating in methane the metallic tantalum in excess could be converted to carbide and the latter thus obtained in the pure state. The diameter of the inner interference ring for pure TaC was determined and has permitted X-ray analysis to be adopted as a routine testing method in the preparation of this carbide.

### 16. Hydrogen in Tantalum

Metallic tantalum can be deposited on a strongly-heated core wire [4]) by thermal decomposition of tantalum pentachloride, Ta $Cl_5$, this method closely resembling the isolation of tungsten from W $Cl_6$ as first achieved by van Arkel [5]). The ductility of the product was found to be by far the best when the Ta $Cl_5$ used had first been sublimed *in vacuo* (such treatment making it, moreover, far more active).

It appeared feasible that this improvement was due to the expulsion of absorbed gases from the Ta $Cl_5$ during sublimation: If theses gases were still present on the isolation of the tantalum, they could be absorbed by the metal and for instance form a solid solution, thus resulting in a reduction in ductility.

This assumption was confirmed by X-ray analysis, for small differences in interatomic distances were found for tantalum wires prepared by different means, a result which could again be deduced from the difference in diameter of the inner interference ring (registered on a "reversed" film). Two exposures so obtained are reproduced in figs. *4a* and *b*, the



a

b

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Fig. 4. X-ray photographs of tantalum prepared from tantalum chloride by thermal decomposition a) with and b) without hydrogen. The greater diameter of the inner interference ring in fig. b) is due to the presence of hydrogen in the metal, which is thus made less ductile.

former relating to metal deposited from pure Ta $Cl_5$ and the latter to metal obtained by decomposition of the chloride in a hydrogen atmosphere. The difference between the diameters of the inner interference rings (a doublet) is 2 mm, which here corresponds to a difference in the lattice constants of approx. 0.2 per cent, the tantalum lattice having been slightly expanded by the absorption of hydrogen.

3) The exposures again show clearly the greater "sensitivity" of the inner lines with respect to the lines further out.

4) W. G. Burgers and J. C. M. Basart, Z. anorg. allg. Chem., **216**, 223, 1924.

5) A. E. van Arkel, Physica, **3**, 76, 1923.

# ABSTRACTS OF RECENT SCIENTIFIC PUBLICATIONS OF THE N.V. PHILIPS' GLOEILAMPENFABRIEKEN *)

**No. 1080:** A. Bouwers: Röntgenapparaten (Ingenieur, **51**, E 27-30, March, 1936).

In this paper the author, with the aid of examples, traces how X-ray technology has succeeded in evolving, from the X-ray tube used in experimental physics, a perfectly safe electrotechnical equipment with *a priori* calculated characteristics. The author discusses the problem of insulating high-tension equipment, with special reference to a simplified method for calculating and providing insulation on high-tension equipment capable of withstanding a uniform stress at a specific field strength, the production of high outputs for short periods, and the generation of very high tensions of the order of several million volts. A series of demonstrations were given, including a small complete X-ray equipment weighing only $3^1/_2$ kg and high-tension generators for a million volts direct voltage and impulse voltages of 2 million volts.

**No. 1081:** R. Vermeulen: Geluidsfilm-apparaten (Ingenieur, **51**, E 30-34, March, 1936).

In the Philips-Miller method, sound films are produced by mechanical means in the same way as gramophone records, whilst the sound track is reproduced by optical means similar to the method employed with the photographically-registered sound film.

As a series of articles on this subject is appearing in this journal (Philips tech. Rev., **1**, 107, 135, 211 and 231, 1936), a fuller abstract of this paper will not be given here.

**No. 1082:** J. van der Mark: Een experimenteele televisiezender en -ontvanger (Ingenieur, **51**, E 37-40, March, 1936).

This paper is almost identical with a paper of the same title contributed by the author to the first number of this journal (cf. Philips techn. Rev., **1**, 16, 1936).

**No. 1083:** M. J. Druyvesteyn: Electron emission of the cathode of an arc (Nature, **137**, 580, Apr. 1936).

In carbon and tungsten arcs electron emission is in general due to the high temperature of the cathode. In the case of the mercury arc it is assumed that electron emission of the cold cathode is due to the powerful electric field produced in front of the cathode by those positive ions which travel towards this electrode. In addition the author assumes also a third mechanism for electron emission from the cathode. According to this hypothesis the cathode is coated, at least partially, with a thin layer of an insulating substance. The positive ions which accumulate on this layer can generate such a powerful field that the metal emits electrons through the insulating layer. These electrons traverse at great speed the space charge of the positive ions, thus having little opportunity to recombine with them. The greater part of the cathode drop is obtained at the insulating layer.

**No. 1084:** J. A. M. van Liempt: Die Dampfdrücke des Caesiums (Rec. Trav. chim. Pays-Bas, **55**, 157-160, March, 1936).

On the basis of previous investigations (cf. Abstract No. **1051**) the author deduces a formula expressing the vapour pressure of caesium as a function of the temperature, which is valid for temperatures between 300 and 1000 deg. K. The most probable sublimation curve is given for temperatures between 270 and 300 deg. K.

**No. 1085:** J. L. Snoek: Sur une nouvelle expérience de magnétostriction (Physica, **3**, 205-206, Apr., 1936).

The reversible torsion phenomena, which according to Perrier are exhibited by a nickel wire after special pre-treatment when temperature changes are produced in the neighbourhood of the Curie point, are no longer observed when the wire has been corroded by hydrogen chloride or when oxidation during pre-treatment is prevented. According to the author these phenomena must be regarded as due to the oxide layer and not to reversible changes in texture as assumed by Perrier.

**No. 1086:** W. Elenbaas: Der Einfluss des Zündgases auf die Quecksilber-Hochdruckentladung (Physica, **3**, 219-236, Apr., 1936).

By measuring the reduction in radiation the author has determined the additional loss in energy per cm of tube length in a high-pressure discharge

*) A sufficient number of reprints for purposes of distribution is not available of those articles marked with an asterik (*). Reprints of other papers may be obtained on application from Philips' Laboratory, Kastanjelaan, Eindhoven, Holland.

through mercury vapour due to the addition of rare gases. This increased loss was found to be practically independent of the energy input per cm of tube length, and could be calculated from the increase in thermal conductivity. On the assumption, that in pure mercury the heat dissipated per cm of tube length is 10 watts, the measurements could be described with the aid of a formula due to Enskog for the thermal conductivity of a gas mixture. In a previous paper (Physica, **2**, 757, 1935) the author arrived at an energy loss of 9 watts per cm from the relationship between the voltage gradient and the energy input. If the additional losses due to the rare gases introduced are also taken into consideration, the influence of the rare gases on the gradient can be calculated by a theoretical method given previously.

**No. 1087:** J. R. J. van Dongen and J. G. C. Stegwee: De beteekenis van de schijfproef als verkorte standtijdproef (Metaalbewerking, **3**, 1-6 and 49-56, March and Apr., 1936).

As a number of articles dealing with this subject have already appeared in this Review (Phil. techn. Rev., **1**, 183 and 200, 1936) a full abstract of this paper is superfluous.

**No. 1088:** K. Posthumus: Richtantennes met identiek richtingsdiagram, maar ongelijke stroomverdeeling (aequivalente antennes). (T. Ned. Rad. Genoot., **7**, 115-139, Apr., 1936).

The author points out that the directional distribution of an aerial made up of a number of similar components situated in a straight line at uniform intervals and having an arbitrary current distribution, can in general also be obtained with several other forms of aerial and a different current distribution. In the aggregate there are $2^{n-1}$ equivalent aerials from $n$ components. It is shown how these equivalent aerials can be deduced from the data for an arbitrary aerial. In conclusion the author points out that the more common aerials in use have no equivalent aerial.

**No. 1089:** J. H. de Boer, W. G. Burgers and J. D. Fast: The transition of hexagonal $\alpha$-titanium into regular $\beta$-titanium at a high temperature (Proc. kon. Akad. Wet. Amsterdam, **39**, 515-519, Apr., 1936).

In isolating zirconium by thermal decomposition of $ZrJ_4$ the metal is deposited in a form with regular symmetry ($\beta$-modification), whilst at ordinary temperature it is obtained with hexagonal symmetry ($\alpha$-modification). Titanium is isomorphous with zirconium and at high temperatures is deposited together with zirconium in the form of mixed crystals. It thus appeared that titanium also would pass over into a regular $\beta$-modification at high temperatures; this was in fact found to be the case from both resistance curves and X-ray photographs. The transition temperature was 882 deg. C and thus differs little from that for zirconium (862 deg. C). Also, as with zirconium, (see Abstract No. **1095**) a well-defined transition temperature is only found when the metal contains no oxygen or nitrogen.

**No. 1090:** J. A. M. van Liempt and J. A. de Vriend: Das Flimmern von Glühlampen bei Wechselstrom (Z. Phys., **100**, 263-266, Apr., 1936).

The flickering of various types of electric lamps when run on a low-frequency alternating current supply was investigated with the aid of a cathode ray tube and a caesium photo-electric cell. At an equivalent wattage spiral filament vacuum lamps showed the least flickering, being followed by straight-filament vacuum lamps and gas-filled coiled-coil lamps; the greatest comparative flickering was obtained with gasfilled single-coil lamps.

**No. 1091:** Balth. van der Pol: Trillingen (Ned. T. Natuurk., **3**, 65-84 and 97-108, Apr., 1936).

A translation of the paper read in English, abstracted under No. **1077.**

**No. 1092:** H. Ziegler: Shot effect of secondary emission. II. (Physica, **3**, 307-316, May, 1936).

The coefficient of secondary emission and the variation in secondary current are governed by the energy of the primary electrons and by the nature of the electrode bombarded. In continuation of a previous paper (cf. Abstract No. **1066**) the author examines the multiple electronic charges composing the current impulse. The quotient of the coefficient of secondary emission and of the coefficient of secondary current fluctuations is a measure of the proportion of effective primary electrons and of the quality of the amplification due to secondary emission in respect of fluctuations in operating conditions. These phenomena are studied for a nickel plate with an activated barium and strontium surface in relationship to the velocity of the primary electrons.